Original Paper

Weed Control in the Maize Stand in Dry Agroecology Conditions

Denis Onufer, Štefan Týr*
Slovak University of Agriculture in Nitra, FAFR, Institute of Agronomic Sciences, Slovakia

Article Details: Received: 2025-09-22 | Accepted: 2025-10-20 | Available online: 2025-12-31

https://doi.org/10.15414/afz.2025.28.04.370-380

The most common active ingredients of herbicides used in maize are, for example: dicamba, rimsulfuron, nicosulfuron, dimethenamid. The experiment was carried out at the PPD Inovec Volkovce farm. The aim of this work was to utilize the possibilities of chemical weed control and analyze them on plots with sown maize. The control of weed species were monitored and the effectiveness of the herbicides used with specific active ingredients applied according to variants: early post-emergent and post-emergent were also evaluated. The partial objectives of the work were: 1. evaluation of the current weed infestation using numerous methods on control and treated variants; 2. evaluation of the effectiveness of regulatory intervention on variants treated with herbicides; 3. evaluation of the phytotoxicity. The experiment was carried out on their standard plots with maize sown according to the sowing plan. Experimental area was set aside each year that has only been sown and has not been further treated. Chemical treatments in the experiment were carried out in accordance with the EPPO PP1/181(5) methodology. Untreated control area was covered with foil during the application of herbicides. Based on the use of available herbicides, the variants were divided into early post-emergence treatment up to the 3rd leaf of maize and post-emergence treatment up to the 6th leaf of maize. The best result had variant with active ingredients dicamba and prosulfuron in early post-emergence treatment.

Keywords: maize, herbicides, treatment timing, weed control, weed infestation

1 Introduction

Maize (*Zea mays* L.) is one of the most important crops in global agriculture, along with rice and wheat. Maize has grown in more than 170 countries around the world with an area of approximately 194 million hectares, with a production of approximately 1,148 million tons. In 2023, the average grain corn yield in Slovakia was 7.86 t.ha^{-1}(Štatistický úrad SR, 2023). The total yield was 1.6 million tons. The cultivation area was 203,165 ha. As a wide-row crop, corn offers a lot of space for weeds, which can drain a significant amount of nutrients, especially in the early stages of growth. If weeds are not eliminated in any way, crop losses of 30% or more are possible. Drought and other harmful factors can cause crop losses of up to 30–35%. Modern agriculture is focused on maximizing yields per hectare, and in such a system, the use of herbicides is probably inevitable. However, everything should be done in moderation, as the indiscriminate use of herbicides can cause disruption to biodiversity, the selection of certain weed species, increased plant resistance to active substances, and so on. In the past, mechanical control and traditional agronomic practices were mainly used, which can lead to a certain reduction of weed seed stock in the soil, but herbicide control is one of the most effective methods. Weed control, like protection against fungal diseases, should be approached sensibly, after careful professional consideration and using a variety of strategies. Every farmer has several options at their disposal, such as tillage, herbicide control and the use of biological products. When choosing a specific method, factors such as the cultivation system, the composition of weeds in the field, the abundance of weeds, the corn variety, but also precipitation and weather must be considered. The goal must always be to eliminate weeds so that they do not take away nutrients and space for the growth and development of maize.

***Corresponding Author:** Štefan Týr, Slovak University of Agriculture in Nitra, FAFR, Institute of Agronomic Sciences, Tr. Andreja Hlinku 2, 949 01 Nitra, Slovak Republic
e-mail: stefan.tyr@uniag.sk, https://orcid.org/0000-0001-7795-7538

1.1 Agroecological Conditions for Growing Maize in Slovakia

Maize (*Zea mays* L.) is a crop that thrives in warm, dry to moderately humid areas. It has a relatively long growing season and, due to its high resistance to drought, is also suitable for sandy soil, where other cereals 'thrive' much less well. Maize requires temperatures of around 19 °C during the phenological flowering phase, which indicates that its heat requirements are relatively high. Despite its good drought resistance, maize needs sufficient soil moisture during emergence and initial growth (Vilček, 2005). In order to achieve the best possible yield and quality, it is very important to select the right hybrid that will suit the site conditions as much as possible. Pre-sowing preparation and ensuring a fine-grained structure are also important. The optimal sowing time is considered to be when the soil temperature reaches at least 8–10 °C. Another condition for proper crop establishment is maintaining the appropriate sowing depth and density. The nutrition and fertilization of maize must be adapted to the expected nutrient uptake, considering the ASP. Maize makes very good use of organic fertilizers and benefits from them (Jančovič, Vozár, 2009).

1.2 Spectrum of Weeds Infestation in Maize

Wide-row crops create excellent conditions for the growth of weeds, which are undesirable for the growth and development of cultivated crops as they draw water, light and, in particular, nutrients from the soil and fertilizers. Maize is particularly sensitive to weed competition during the first 40 to 50 days after emergence. Due to cost reduction, mechanical treatments (weeding) are increasingly being omitted, and therefore it is necessary to focus on the application of herbicides (Týr, 2003). Weeds are defined as any undesirable plant and are considered one of the main problems in agricultural fields. Although weeds exhibit a diverse set of characteristics, most of them tend to show increased above-ground biomass in response to nutrient supply and quickly interfere with crop growth. High weed pressure negatively affects productivity, mainly due to competition for limited resources, including nutrients, water and light (Bretas et al., 2024). Of all the biotic and abiotic factors that threaten maize, weeds are considered one of the most important aspects limiting the yield of this crop. Corn does not compete with weeds for at least a month after sowing, allowing them to grow freely. Currently, there are more than 100 species of weeds in corn, of which approximately 40 are common and can lead to a significant reduction in yield of up to 85% (Da Silva Brochado et al., 2022). Although weeds are considered a negative factor in crop cultivation, they can sometimes be beneficial. In drier areas, some weed species act as living compost, preventing water evaporation from the soil and soil erosion. Some weed species even improve soil fertility by capturing nitrogen. Others serve as food for animals, pollinators and other beneficial insects (Hasan et al., 2021). Recently, we have been encountering more and more invasive, introduced weed species in vegetation, which poses great danger. Invasive species include the weeds mentioned above, mainly: *Ambrosia artemisiifolia* L., *Conium maculatum* L., *Iva xanthiifolia* Nutt., *Abutilon theoprasti* L., *Xanthium strumarium* L. and others (Týr – Vereš, 2012). The species with the highest frequency of occurrence (persistence) include: *Chenopodium album* (L.), *Viola arvensis* (L.), *Fallopia convolvulus* (L.), *Polygonum aviculare* (L.), *Cirsium arvense* (L.) and *Tripleurospermum inodorum* (L.). Of the recorded species, 43% were apophytes, 49% were archaeophytes and 8% were neophytes. In the conventional farming system, 133 weed species were found, while in the organic system there were 177. The organic farming system recorded more than twice the average species richness than the conventional system. The average number of weed species in the catchment area increased with altitude in both farming systems (Kolářová, 2024).

1.3 Weed Control

The use of herbicides as a chemical means of weed control is now an integral part of cultivation practices on every farm. The term 'herbicide' refers to an active substance or substances that, through a specific mechanism of action, lead to the elimination of weed species in cultivated crops (Braz et al., 2022). The mechanism of action must be varied and regularly changed to prevent the development of resistance. The aim of using herbicides should not be to completely eliminate weeds on the land, but to reduce their numbers below the threshold of harmfulness and also to reduce their seed reserves in the soil (Manzone, 2020). Like everything else, herbicides have both positive and negative sides. The positive side is that the advent of effective herbicides has significantly reduced the need for human labor, which means lower costs. Another positive aspect is, of course, their effectiveness and the fact that they enable the potential of the cultivated crop to be exploited (Wardak et al., 2025). The negative side is the demonstrable impact on the environment and the increasingly frequent presence of active substances in groundwater (Guerra et al., 2022). The herbicidal effect is manifested by biochemical and/or physical mechanisms that cause the death of the target organism (Jin et al., 2021). Their manifestation can vary from color change, tissue necrosis, leaf deformation to complete wilting. Some mechanisms disrupt the cell membrane of plants, which can directly or indirectly disrupt metabolic processes. When selecting and using a specific herbicide, it is very important to correctly identify the species to which the herbicide is to be applied and to adhere to the dosage and method of application (Li et al., 2022). Herbicides that inhibit acetolactate synthase have the highest number of reported cases of resistance worldwide, especially in monocotyledonous weeds. They belong to the most widely used group of herbicides, and their application is increasing every year. Therefore, new cases of resistance to this mode of action are expected to occur in many weed species (Heap, 2022). The effectiveness of herbicides is influenced by several factors, the main ones being (Champion, 2019): Temperature: most of the active ingredients contained in herbicides are ineffective at low temperatures and their application during such periods is ineffective. As a rule, the effectiveness of herbicides increases with rising temperatures. Precipitation: heavy rainfall shortly after the application of a non-soil-active herbicide can completely wash away the active ingredients, rendering the application completely ineffective. On the contrary, moderate rainfall is desirable for soil herbicides. Heavy rainfall shortly after application causes the active ingredients to be washed into the lower soil layers, where phytotoxicity to the cultivated crop may occur. Wind speed: The application of herbicides is generally affected by wind speed, which can cause drift and possibly damage to neighboring crops. Sunlight: sunlight, or rather its intensity, mainly affects herbicides that disrupt photosynthesis. Other factors include soil type, soil pH, microorganisms, humus content and soil moisture, which also have a significant impact on the overall effect of the herbicides used. Therefore, it is assumed that changing climatic conditions will have a major impact on weed biology, their growth characteristics and their management (Kumar et al., 2023). Busi et al. (2020) argue that chemical weed control is stress-free, flexible and relatively inexpensive compared to mechanical control. In addition, chemical control is suitable for various climatic and soil conditions. Even on very heavy or lighter soils, it has proven to be more effective than mechanical cultivation. The main task of proper weed control is to keep weeds below the threshold of economic, ecological and, last but not least, economic harmfulness. Weed control creates suitable conditions for optimal growth and development of the cultivated crop (Sohn et al., 2021). Weed control in maize is usually limited to one herbicide treatment, but the application of two or more herbicides has many advantages, e.g. broadening the spectrum of weed control, reducing the risk of crop damage by using lower herbicide doses, and limiting herbicide residues in the soil or crop (De Cauwer et al., 2023). In general, total herbicides are non-selective before sowing and are used to eliminate prevalent complex annual and perennial weeds, especially thistles (Allmendinger et al., 2022). Ding et al. (2021) claims that the maximum effectiveness of such an herbicide can be achieved by applying it before sowing and lightly incorporating the active ingredient into the soil. It has been found that some herbicides, such as carfentrazone-ethyl, pendimethalin and growth regulator-inhibiting herbicides, are less effective against certain weeds. Pre-emergence herbicides containing dimethenamid, terbuthylazine and S-metolachlor usually provide the most effective protection for future maize crops. In case of control failure or absence of pre-emergence treatment, herbicides containing, for example, dicamba or various sulfonylureas can be applied after emergence (Šuk et al., 2023). However, if one herbicide is used repeatedly over a long period of time to control the same weeds, resistance may develop. Therefore, it is necessary to avoid long-term, continuous use of the same herbicide. Herbicides with different modes of action should be alternated to prevent weeds from developing resistance to specific active ingredients. Scientists have found that the application of two or more compatible herbicides used as a tank mix is more effective in controlling a wider range of weeds, including grasses, than the application of a single active ingredient alone (Alam et al., 2021). Most research in organic conditions – comparing some of the alternative systems – has concluded that weed management remains the main challenge in organic maize production. In addition, weather and environment significantly influence the possibilities/effects related to weed management systems and crop development (Schmidt et al., 2023). The residual effectiveness of pre-emergence herbicide treatment for weed control depends on several variables, including environmental conditions (i.e. amount of rainfall after application, temperature), the physical and chemical properties of the herbicide (i.e. water solubility, vapor pressure, octanol-water coefficient, acid ionization constant), the physical and chemical properties of the soil (i.e. pH, organic matter, structure) and the composition of the weed community in the soil. Effective weed control at the beginning of the season can be achieved with pre-emergence herbicides if these factors are favorable for the correct chemical intervention. However, if any of these conditions are not favorable, weed control at the beginning of maize growth may fail (Silva et al., 2023). For many years, glyphosate-based herbicides were used without seriously endangering crops. However, overuse, misuse and overreliance on glyphosate have led to the emergence of glyphosate-resistant weeds and made it necessary to use herbicides such as dicamba. In addition, dicamba-resistant crops such as soybeans have emerged, but the use of dicamba has spread again and this herbicide is currently one of the most widely used, with interest in the use of auxin herbicides increasing significantly. Dicamba, applied alone or in tank mixes, can effectively control several weed species, including several glyphosate-resistant weeds (Traylou et al., 2024). The aim of this study was to utilize the possibilities of chemical weed control and analyze them on land planted with maize. Weed species control was monitored, and the effectiveness of the herbicides used, and specific active substances applied according to variants (early post-emergent and post-emergent) was evaluated. The partial objectives of the work were to evaluate the current weed infestation using a numerical method on the control and treated variants, to make a video recording of the control area (control = untreated), to assess the effectiveness of the control intervention on the variants treated with herbicides, to assess the possible phytotoxicity of the applied herbicides according to the variants, and evaluating the weight of the pods from each variant in comparison with the control.

2 Material and Methods

The experiment was carried out at the PPD Inovec Volkovce farm, which was located in dry agroecology conditions near Zlaté Moravce. The PPD Inovec Volkovce farm manages an area of 1700 ha. They grow winter wheat on a total area of approximately 490 ha, winter rapeseed on 400 ha, sunflowers on 80 ha and grain maize on an area of approximately 150 ha. A large part of the land is also covered by permanent grassland. Brown soils are found in almost the entire area. Pseudogley brown soils and several subtypes of cambisols predominate, with a predominance of pseudogley cambisols, typical cambisols and regosols. Of the subtypes of brown soils associated with the undulating hilly part of the cadastral area, eroded brown earth predominates. Along watercourses, there are fluvisols (alluvial soils) with a predominance of the gley fluvisol subtype. The forested areas have developed on forest soil subtypes. These are lined in the lower parts mainly by typical brown soils and eroded brown soils. Overall, the soils within the cooperative's territory are classified as very productive to productive. The village of Volkovce is located in the northern part of the Pohronská pahorkatina hills in the Bočovka river valley on the southern slopes of Pohronský Inovec. The altitude of the area ranges from 220 to 450 metres above sea level. The north-eastern part of the area is mostly covered by oak forest, while the rest is deforested and used for agriculture. The terrain is moderately undulating and hilly. The Bočovka stream flows through the cadastral territory and flows into the Širočina watercourse, which joins the Žitava river in Vráble. The territory of the municipality belongs to the climatic region of temperate latitudes. The average annual air temperature is 9 °C, with July being the warmest month (average 18.7 °C) and January and February being the coldest months (-1.8 °C). The period with an average temperature above 10 °C begins in mid-April and ends in mid-October. The average number of summer days per year in this area is 63. There is an average of 14 days when the air temperature rises above 30 °C, known as tropical days. There are an average of 22 frost days (with a minimum temperature of -0.1 °C). Precipitation, which is most important for the growth of maize and weeds, is very low between April and June. In winter, south-easterly, easterly and north-easterly winds prevail, while in summer, westerly winds prevail (internal source: PPD Inovec Volkovce, 2022). The implementation took place on their standard plots with maize sown according to the sowing plan. The supply of weed seeds on the plots of this farm was sufficient, so there was not risk of contamination or distortion of the experimental results due to weed-free soils. In agreement with the agronomist, an area of 8 areas was set aside where corn was only sown without any other agrotechnical measures that were carried out across the entire field. Chemical treatments were carried out individually using a manual experimental sprayer. Used dose of water was 300 liters per hectare. The experiment was carried out in accordance with the EPPO PP1/181(5) methodology (EPPO database, 2021). Untreated control area was covered with foil during the application of herbicides. The soil was sufficiently prepared before and at sowing and the weeds were removed mechanically. The evaluation of the weeds in variant V3 was conducted prior to the application of dicamba, rimsulfuron, nicosulfuron + adjuvant (Kelvin Quattro + Dash). Evaluation of herbicide efficacy described in Tables 5, 6 was conducted 21 DAT which is the optimal time to determine herbicide efficacy on specific weed species. The statistical evaluation of the results obtained was performed using the TIBCO StatisticaTM program 13.6.0. The evaluation of the results obtained has been evaluated on the basis of the Bonitation scale given in Table 1 and Table 2. To calculate the effect of herbicides in %, we need Abott's formula, which is as follows:

$$U = \frac{O - K}{O} \cdot 100$$

where: U – herbicide efficacy in %; O – number of living weeds in untreated control; K – number of living weeds after weed control

Table 1 Bonitation scale for assessing the effect of herbicides (part 1)

Degree of weed cover			Effect of herbicide on weeds		
%	value	symptoms on plants	%	value	in words
0.00	1	stand without live weeds	100.00	1	excellent
2.50	2	occasional weeds still alive	97.50	2	very good
5.00	3	small amount of weeds still alive, strong weed damage	95.00	3	good
10.00	4	part of weeds still alive, clear weed damage	90.00	4	satisfactory
15.00	5	weed damage still evident	85.00	5	satisfactory
25.00	6	weed damage insufficient	75.00	6	insufficient
35.00	7	slight weed damage, largely still growing	65.00	7	weak
67.50	8	insignificant damage, weeds developing almost normally	32.50	8	very weak
100.00	9	no damage, weeds growing as in untreated plot	0.00	9	none

Source: Týr, Vereš, 2012

Table 2 Bonitation scale (part 2)

Effect of the herbicide on crop plants (phytotoxicity)		
Symptoms on cultivated crops	%	value
No damage at all	0.00	1
Individual leaves slightly damaged	2.50	2
Occasional damaged leaves and slight stunting of growth	5.00	3
Most of the leaves damaged, noticeable stunting	10.00	4
Severe damage to leaves which are not yet dying, but stunting is evident	15.00	5
Entire plant damaged	25.00	6
Partial leaf death	35.00	7
Leaves dead, partial death of entire plant	67.50	8
Plants dead	100.00	9

Source: Týr, Vereš, 2012
The assessment of phytotoxicity on the corn stand was evaluated based on a Bonitation scale part 2

2.1 Treatment Distribution and Characteristics

Treatments in the field experiment were divided into 3 categories. The first category was early-postemergent herbicides and the second category was post-emergent herbicides, the last one was untreated control based on variants in Table 3. The experiment also included untreated control and a variant of the farm technology, which served to compare the different herbicides applied. Herbicide rates were always set according to the applicable label and with the recommended water rate per hectare, which was 300 litres. Application dates were in accordance with agronomic practice. The date of early-postemergent application was May 8, 2023. Growth stage of weed was BBCH 10-12 and growth stage of maize was BBCH 13-14. The postemergent application was May 22, 2023 and growth stage of weed was BBCH 16-17 and growth stage of maize was BBCH 16-17.

3 Results and Discussion

Based on the implementation of experiments according to the established methodology and variants, information on the weed occurrence and effectiveness of regulatory interventions was continuously obtained. The results obtained were evaluated and conclusions were drawn based on the evaluations. The maize crop variants studied included the weeds *Chenopodium album* L., *Echinochloa crus-galli* L., *Anthemis arvensis* L. and winter rape, which was grown as a pre-crop on the plot. According to the rating scale (Tables 1, 2), it is possible to evaluate the efficacy of dicamba, rimsulfuron, nicosulfuron + adjuvant (Kelvin Quattro herbicide with Dash) as excellent to very good on the listed weed species. Interestingly, the above herbicide showed phytotoxicity after application but ultimately had no significant effect on crop quality and yield. The evaluation of the weed occurrence of variant V5 was carried out before the application of dicamba, prosulfuron + adjuvant (Casper 55 WG + Dash) herbicide

Table 3 Distribution of treatments into groups

Groups of treatment	Active ingredients, herbicides, adjuvants	Variant No.	Dose
Untreated control	–	V0	–
Early postemergent	dicamba, rimsulfuron, nicosulfuron + phospate esters, methyl ester of palmitic and oleic acid, oleic acid	V3 – Kelvin Quattro + Dash	0.48 kg.ha^{-1} + 0.5 l.ha^{-1}
	dicamba, prosulfuron + phospate esters, methyl ester of palmitic and oleic acid, oleic acid	V5 – Casper 55 WG + Dash	0.3 kg.ha^{-1} + 0.5 l.ha^{-1}
Postemergent	tembotrione	V7 – Laudis OD	2.2 l.ha^{-1}
	mesotrione, nicosulfuron + alkyphenolalkoxylate	V8 – Callisto 100 SC + Milagro 4 SC + Šaman	1.0 + 1.0 + 0.5 l.ha^{-1}

at the 3-leaf stage of maize. The application itself took place at the same 3-leaf stage of maize; the product was applied early-postemergent. The evaluation of herbicide efficacy described in Tables 7, 8 took place 21 DAT which is the optimum time to determine herbicide efficacy on specific weed species. According to the rating scale (Tables 1, 2), the efficacy of Casper 55 WG herbicide with Dash can be rated as excellent to very good on the listed

Table 4 Weed species present during the assessment in variant V0 on 8. 5. 2023

Inclusion in the system	Weed name	Number of weeds per m^2			
		r1	r2	r3	average
Late spring weeds	*Echinochloa crus-galli* L.	5.00	7.00	3.00	5.00
	Chenopodium album L.	64.00	48.00	54.00	55.34
Winter weeds	*Anthemis arvensis* L.	3.00	2.00	3.00	2.67
Previous crop residue	*Brassica* spp.	2.00	1.00	2.00	1.67
Total per m^2		74.00	58.00	62.00	64.67
Average per m^2					64.67

r1, r2, r3 – repetitions

Table 5 Weed species present during the assessment in variant V3 on 8. 5. 2023

Inclusion in the system	Weed name	Number of weeds per m^2			
		r1	r2	r3	average
Late spring weeds	*Echinochloa crus-galli* L.	2.00	1.00	1.00	1.33
	Chenopodium album L.	36.00	32.00	41.00	36.33
Winter weeds	*Anthemis arvensis* L.	1.00	3.00	2.00	2.00
Previous crop residue	*Brassica* spp.	1.00	4.00	7.00	4.00
Total per m^2		40.00	40.00	51.00	43.67
Average per m^2					43.67

r1, r2, r3 – repetitions

Table 6 Weed species (V3) according to the efficacy of the selected herbicide based on the rating scale (rating 21 DAT, on 29. 5. 2023)

Inclusion in the system	Weed name	Herbicide efficacy, value		
		r1	r2	r3
Late spring weeds	*Echinochloa crus-galli* L.	1	1	1
	Chenopodium album L.	1	1	1
Winter weeds	*Anthemis arvensis* L.	1	1	1
Previous crop residue	*Brassica* spp.	2	2	2

r1, r2, r3 – repetitions

Table 7 Weed species present during the assessment in variant V5 on 8. 5. 2023

Inclusion in the system	Weed name	Number of weeds per m²			
		r1	r2	r3	average
Late spring weeds	*Echinochloa crus-galli* L.	5.00	6.00	3.00	4.66
	Chenopodium album L.	18.00	21.00	23.00	20.66
Winter weeds	*Anthemis arvensis* L	1.00	2.00	2.00	1.66
Previous crop residue	*Brassica* spp.	1.00	1.00	1.00	1.00
Total per m²		25.00	30.00	29.00	28.00
Average per m²					28.00

r1, r2, r3 – repetitions

Table 8 Weed species (V5) according to the efficacy of the selected herbicide based on the rating scale (rating 21 DAT, on 29. 5. 2023)

Inclusion in the system	Weed name	Herbicide efficacy, value		
		r1	r2	r3
Late spring weeds	*Echinochloa crus-galli* L.	9	9	9
	Chenopodium album L.	1	2	2
Winter weeds	*Anthemis arvensis* L.	1	1	1
Previous crop residue	*Brassica* spp.	2	2	2

r1, r2, r3 – repetitions

Table 9 Weed species present during the assessment in variant V7 on 22. 5. 2023

Inclusion in the system	Weed name	Number of weeds per m²			
		r1	r2	r3	average
Late spring	*Echinochloa crus-galli* L.	6.00	7.00	4.00	5.66
	Chenopodium album L.	48.00	43.00	49.00	46.66
Winter weeds	*Anthemis arvensis* L.	1.00	2.00	2.00	1.66
Previous crop residue	*Brassica* spp.	2.00	3.00	2.00	2.33
Total per m²		57.00	55.00	57.00	56.33
Average per m²					56.33

r1, r2, r3 – repetitions

Table 10 Weed species (V7) according to the efficacy of the selected herbicide based on the rating scale (rating 21 DAT, on 12. 6. 2023)

Inclusion in the system	Weed name	Herbicide efficacy, value		
		r1	r2	r3
Late spring	*Echinochloa crus-galli* L.	1	1	1
	Chenopodium album L.	1	1	1
Winter weeds	*Anthemis arvensis* L.	1	1	1
Previous crop residue	*Brassica* spp.	2	2	2

r1, r2, r3 – repetitions

weed species and no effect on Eurasian watermilfoil. However, hedgehog curiae are not even declared in the efficacy of dicamba, prosulfuron (Casper 55 WG), since it is a two-leaf weed control product. The evaluation of the V7 variant weed occurrence was carried out before the application of tembotrione (Laudis OD) at the 6-leaf stage of maize, the product was applied post emergently.

The evaluation of herbicide efficacy described in Tables 9, 10 took place 21 DAT which is the optimum time to determine herbicide efficacy on specific weed species. According to the rating scale (Tables 1, 2), it is possible to evaluate the efficacy of tembotrione (Laudis OD) as excellent to very good on the listed weed species. In this case, it should also be noted that the efficacy was excellent to very good even though the weeds listed were already considerably overgrown (high growth stage). The evaluation of the weeds in variant V8 (farm technology) was carried out before the application of the mesotrione, nicosulfuron + alkyphenolalkoxylate (Callisto 100 SC + Milagro 4 SC + Šaman) at the 6-leaf stage of maize.

The evaluation of herbicide efficacy described in the tables took place 21 DAT, which is the optimum time to determine herbicide efficacy on specific weed species. According to the rating scale (Tables 1, 2), it is possible to evaluate the efficacy of the mesotrione, nicosulfuron (Callisto 100 SC + Milagro 4 SC) in tank-mix as excellent to very good on the listed weed species. In this case, it should also be noted that the efficacy was excellent to very good even though the above weeds were already considerably overgrown (high growth stage). The three most important and common maize diseases monitored were maize stunt, maize fusarium wilt and maize powdery mildew. Maize stunt on the tips of the ears and fusariosis between the kernels were very rare in the crop, but this was practically not reflected in the yield. The yield of the plot was 8,8 $t.ha^{-1}$. Harvesting of the cobs from the individual variants took place 2 days

Table 11 Weed species present during the assessment in variant V8 on 22. 5. 2023

Inclusion in the system	Weed name	Number of weeds per m^2			
		r1	r2	r3	average
Late spring	*Echinochloa crus-galli* L.	8.00	4.00	2.00	4.66
	Chenopodium album L.	51.00	37.00	43.00	43.66
Winter weeds	*Anthemis arvensis* L.	3.00	2.00	4.00	2.33
Previous crop residue	*Brassica* spp.	5.00	2.00	1.00	2.66
Total per m^2		67.00	45.00	50.00	54.00
Average per m^2					54.00

r1, r2, r3 – repetitions

Table 12 Weed species according to the efficacy of the selected herbicide based on the rating scale (rating 21 DAT, on 12. 6. 2023)

Inclusion in the system	Weed name	Herbicide efficacy, value		
		r1	r2	r3
Late spring	*Echinochloa crus-galli* L.	1	1	1
	Chenopodium album L.	1	1	1
Winter weeds	*Anthemis arvensis* L.	1	1	1
Previous crop residue	*Brassica* spp.	2	1	2

r1, r2, r3 – repetitions

Table 13 Results of the Student's *t*-test where $P = 0.05$

Variant group	Variant No.	Average number of weeds per m^2 before application	Average number of weeds per m^2 after last application in variants	$P = 0.05$
Untreated control	V0	64.67	64.67	-
Early postemergent	V3	42.67	2.00	0.0001
	V5	28.00	6.00	0.002
Postemergent	V7	56.33	3.00	0.001
	V8	54.00	2.00	0.0001

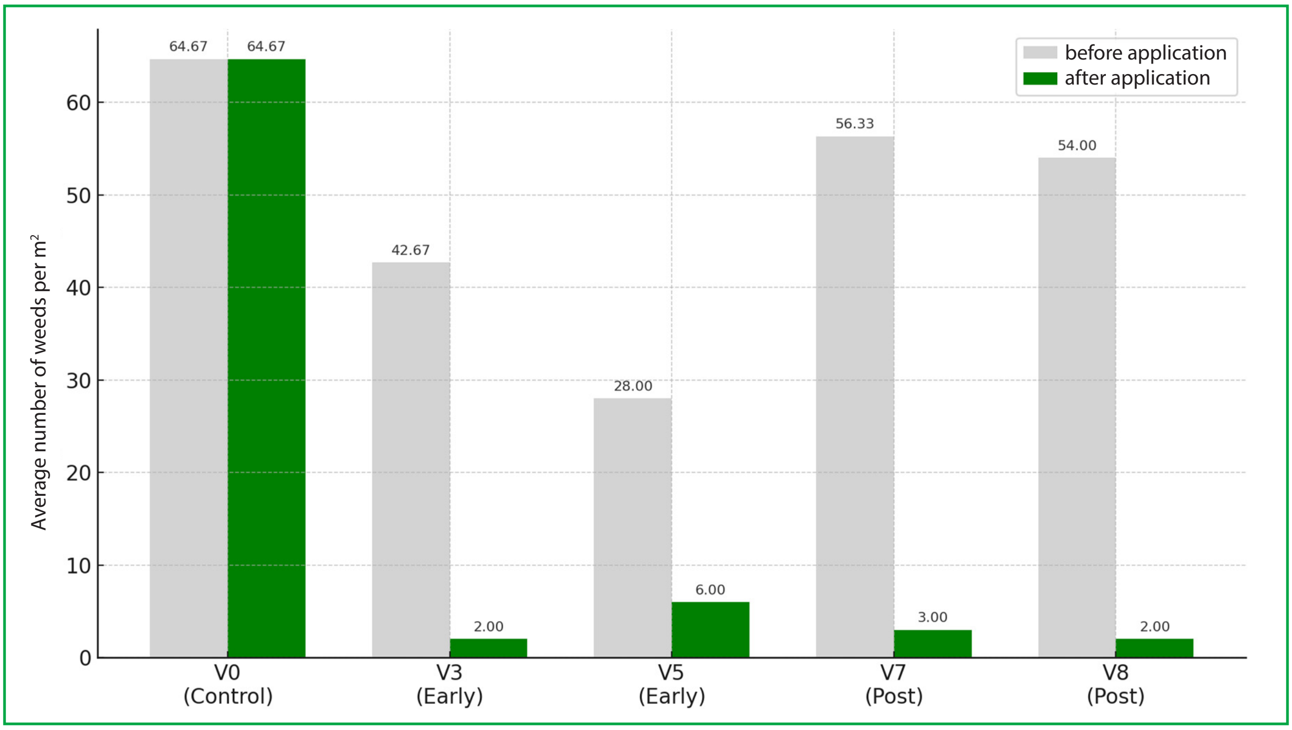

Figure 1 Comparison of weed numbers before and after application

Figure 2 Herbicides efficacy by treatment

before the harvest. On the basis of the data collected and tabulated, a statistical evaluation of the effectiveness of the weed control was carried out using Student's *t*-test. The Student's *t*-test resulted in a *P*-value. The difference in the abundance of weeds in the untreated and treated maize stand is demonstrable, as can be observed in Table 13.

Table 13 also includes the *P*-values that are added above the "After application" columns. These values express the statistical significance of the differences compared to the control variant (V0). A lower *P*-value means greater confidence that the difference is not random – hence higher intervention effectiveness. The evaluation of the efficacy of the herbicides used was calculated using Abott's formula. In variant V3, dicamba, rimsulfuron, nicosulfuron + phospate esters, methyl ester of palmitic and oleic acid, oleic acid (Kelvin Quattro + Dash) were applied with an efficacy of 95.31%. In variant V5, dicamba, prosulfuron + phospate esters, methyl ester of palmitic and oleic acid, oleic acid (Casper 55 WG + Dash) were applied and achieved an efficacy of 78.57%. In variant V7, tembotrione (Laudis OD) active ingredient was applied with an efficacy of 94.67%. In the last variant V8 (farm technology), an efficacy of 96.29% was obtained using the combination of mesotrione, nicosulfuron + alkyphenolalkoxylate (Callisto 100 SC + Milagro 4 SC + Šaman). Figure 1 shows a comparison of the average number of weeds per m^2 before and after herbicide application in each variant.

4 Conclusion

The experiment was located in dry agroecology conditions in Volkovce, Zlaté Moravce district. Based on the trials conducted and their evaluations at the three herbicide application dates (untreated control, early post-emergent, post-emergent) chosen by the grower, it is possible to grow maize without the risk of potentially reducing the economic yield and returns from cultivation. The dominant weed species were *Chenopodium album* L. and *Echinochloa crus-galli* L. From the group of early-postemergent formulations, these weed species were very successfully controlled by dicamba, rimsulfuron, nicosulfuron + phospate esters, methyl ester of palmitic and oleic acid, oleic acid (Kelvin Quattro + Dash) and from the group of postemergent formulations it was tembotrione (Laudis OD).

Acknowledgment

The work was supported by the project VEGA 1/0591/25: "Intercrops for improvement of ecosystem services in sustainable agriculture: focus on regenerative soil processes, crop productivity and stress resistance".

Conflict of Interest

I declare that there is no conflict of interest in the writing of this paper and in the conduct of the experimental work.

Author Contributions

Štefan Týr: conceptualization, formal analysis, funding acquisition, investigation, methodology, project administration, resources, software, supervision, validation, writing – original draft, writing – review & editing; Denis Onufer: data curation, formal analysis, investigation, resources, formal analysis, funding acquisition, software, validation, visualization, writing – original draft, writing – review & editing.

AI and AI-Assisted Technologies Use Declaration

No generative AI tools/AI-assisted technologies were used during the preparation of the manuscript.

References

Alam, P. et al. (2021). Effect of pre and post-emergence herbicides on growth, yield and economics of linseed (*Linum usitatissimum* L.) under irrigated medium land condition of Jharkhand. *The Pharma Innovation Journal*, 10(5), 293–297.

Allmendinger, A., Spaeth, M., Saile, M., Peteinatos, G.G., & Gerhards, R. (2022). Precision chemical weed management strategies: A review and a design of a new CNN-based modular spot sprayer. *Agronomy*, 12(7), 1620.
https://doi.org/10.3390/agronomy12071620

Braz, G.B.P., & Takano, H.K. (2022). Chemical control of multiple herbicide-resistant *Amaranthus*. A review. *Advances in Weed Science*, 40(2), e0202200062. https://doi.org/10.51694/AdvWeedSci/2022;40:*Amaranthus*009

Bretas, I.L., Dubeux, J.C.B., Jr., Zhao, C., Queiroz, L.M.D., Flynn, S., Ingram, S., Oduor, K.T., Cruz, P.J.R., Ruiz-Moreno, M., Loures, D.R.S., Valente, D.S.M., & Chizzotti, F.H.M. (2024). Detection and mapping of *Amaranthus spinosus* L. in bermudagrass pastures using drone imagery and deep learning for a site-specific weed management. *Agronomy Journal*, 1–13.
https://doi.org/10.1002/agj2.21545

Busi, R. et al. (2020). Cinmethylin controls multiple herbicide-resistant *Lolium rigidum* and its wheat selectivity is P450-based. *Pest Manag Sci,* 76, 2601–2608.

Da Silva Brochado, M.G., Mielke, K.C., de Paula, D.F., Souza Laube, A.F., Alcántara-de la Cruz, R., Pereira Gonzatto, M., & Ferreira Mendes, K. (2022). Impacts of dicamba and 2,4-D drift on 'Ponkan' mandarin seedlings, soil microbiota and *Amaranthus retroflexus*. *J. Hazard. Mater. Adv*., 2022, 6, 100084.

De Cauwer, B., De Meuter, I., De Ryck, S., Dekeyser, D., Zwertvaegher, I., & Nuyttens, D. (2023). Performance of drift-reducing nozzles in controlling small weed seedlings with contact herbicides. *Agronomy,* 2023, 13, 1342.

Ding, J. et al. (2021). Tillage and seeding strategies for wheat optimizing production in harvested rice fields with high soil moisture. *Sci. Rep*., 2021, 11, 119.

EPPO database. (2021). Available at: https://pp1.eppo.int/standards/PP1-181-5 (date of citation 2024-03-04).

Guerra, J.G., et al. (2022). How weed management influence plant community composition, taxonomic diversity and crop yield: A long-term study in a Mediterranean vineyard. *Agriculture, Ecosystems & Environment*, 326, 107816.

Hasan, A.S.M.M., Sohel, F., Diepeveen, D., Laga, H., & Jones, M.G.K. (2021). A survey of deep learning techniques for weed detection from images. *Computers and Electronics in Agriculture*, 184, 106067. https://doi.org/10.1016/j.compag.2021.106067

Heap, I. (2022). *The International Survey of Herbicide Resistant Weeds*. Westminster, Weed Science Society of America. Available at: http://weedscience.org (date of citation 2024-05-10).

Champion, P. (2019). *Best Management Practice for Aquatic Weed Control, Part One: The Framework*. Hamilton, New Zealand: National Institute of Water & Atmospheric Research Ltd. Client Report (82 p.).

Jančovič, J., & Vozár, Ľ. (2009). *Principles and perspectives of growing forage on arable land* (*Zásady a perspektívy pestovania krmovín na ornej pôde*). Available at: http://www.agroporadenstvo.sk/rv/krmoviny/krmoviny_orpoda.htm [date of citation 2024-03-11].

Jin, X., Che, J., & Chen, Y. (2021). Weed identification using deep learning and image processing in vegetable plantation. Online. *IEEE Access*, 9, 10940–10950. https://doi.org/10.1109/ACCESS.2021.3050296

Kolářová, M. (2024). *Weed occurrence on agriculturally managed soils and factors affecting the composition of weed communities* (*Výskyt plevelu na zemědelsky obhospodarované pude a faktory pusobíci na složení plevelových spoločenstev)*. Habilitation thesis, CAU Prague (183 p.).

Kumar, V., Kumari, A., Price, A.J., Bana, R.S., Singh, V., & Bamboriya, S.D. (2023). Impact of Futuristic Climate Variables on Weed Biology and Herbicidal Efficacy. A Review. *Agronomy,* 2023, 13, 559. https://doi.org/10.3390/agronomy13020559

Li, J. et al. (2022). Returns to public investments in clean plant centers: A case study of leafroll virus-tested grapevines in support of cost-effective grape production systems. *Journal of Wine Economics*, 1–16.

Manzone, M. et al. (2020). Technical solutions for under-row weed control in vineyards: Efficacy, costs and environmental aspects analysis. *Journal of Agricultural Engineering*, 51(1), 36–42.

Personal consultation at the company to obtain basic information about the land where the experiment was carried out, on November 10, 2022 (Interný zdroj PPD Inovec Volkovce. (2022). Osobná konzultácia na podniku za účelom získavania základných informácií o pozemku, kde bol pokus realizovaný, dňa 10. 11. 2022).

Schmidt, F., Böhm, H., Graß, R., Wachendorf, M., & Piepho, H.P. (2023). Management Effect on the Weed Control Efficiency in Double Cropping Systems. *Agronomy,* 2023, 13, 467. https://doi.org/10.3390/ agronomy13020467

Silva, T.S., Arneson, N.J., DeWerff, R.P., Smith, D.H., Silva, D.V., & Werle, R. (2023). Preemergence herbicide premixes reduce the risk of soil residual weed control failure in corn. *Weed Technol.,* 37, 410–421. https://doi.org/10.1017/ wet.2023.45

Sohn, S.I., Oh, Y.J., Pandian, S., Lee, Y.H., Zaukuu, J.L. Z., Kang, H.J., Ryu, T.H., Cho, W.S., Cho, Y.S., & Shin, E.K. (2021). Identification of *Amaranthus* species using visible-near-infrared (Vis-NIR) spectroscopy and machine learning methods. *Remote Sensing*, 13(20), 4149. https://doi.org/10.3390/rs13204149

Šuk J., Mikulka J., Sen M.K., Košnarová P., Hamouzová K., & Soukup J. (2023). First cases of herbicide resistance of *Tripleurospermum inodorum* in the Czech Republic. *Plant Soil Environ*., 69, 81–87.

Travlou, E., Antonopoulos, N., Gazoulis, I., & Kanatas, P. (2024). Chemical Weed Control and Crop Injuries Due to Spray Drift: The Case of Dicamba. Agrochemicals, 2024, 3, 22–28. https://doi.org/10.3390/agrochemicals3010003

Týr, Š. (2003). *Weed control in corn stands* (*Regulácia burín v porastoch kukurice*). Available at: http://www.agroporadenstvo.sk/ochrana/burkuk.htm?start (date of citation 2024-03-12ň.

Týr, Š., & Vereš, T. (2012). *Weed science* (*Náuka o burinách*). Slovak University of Agriculture (129 p.).

Týr, Š., Olšovská, K., Kupec, M., Štefanko, A., Sóki, S.G., & Majtán, K. (2024). Weeds as an indicator of biodiversity of the cultivation systems (Korovi kao indikator biodiverziteta sistema gajenja). In *Kvalitet zemljišta AP Vojvodine značaj diverzifikacije proizvodnje za očuvanje zemljišta* (1st ed.). *Kvalitet zemljišta AP Vojvodine značaj diverzifikacije proizvodnje za očuvanje zemljišta*. Univerzitet u Novom Sadu (pp. 11–17).

Vilček, J. (2005). *Suitability of agricultural land for growing corn* (*Vhodnosť poľnohospodárskeho pôdneho fondu pre pestovanie kukurice*). Available at: http://www.podnemapy.sk/portal/verejnost/multifunkcne/kuk_repka.aspx (date of citation 2024-03-22).

Wardak, D.L.R., Padia, F.N., de Heer, M.I., Sturrock, C.J., & Mooney, S.J. (2025). Zero-Tillage Induces Reduced Bio-Efficacy Against Weed Species *Amaranthus retroflexus* L. Dependent on Atrazine Formulation. *Agronomy,* 2025, 15, 360. https://doi.org/10.3390/agronomy15020360