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Regulation of the weed component in the maize phytocoenosis using herbicides for the sustainable functioning of agroecosystems

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Abstract. Maize is a crop with low competitive ability against weeds, especially at the early stages of growth and development. The problem of weed infestation in maize crops during the critical period of vegetation remained one of the key factors and led to a substantial reduction in the realisation of the crop yield potential. The purpose of the study was to evaluate the effectiveness of herbicide application for regulating the weed component in the maize phytocoenosis and its impact on yield formation. The research was conducted during 2024-2025 under the conditions of Biryts Shevchenko LLC in Zhytomyr region on soddy medium-podzolic soils. The effectiveness of herbicides for regulating segetal vegetation in the phytocoenosis of three maize hybrids depending on the timing and application rates was highlighted. The combined application of the pre-emergence herbicide Primextra TZ Gold and the post-emergence herbicide Elumis ensured a reduction in the number of grass and broadleaf weeds in the maize phytocoenosis. The highest indicators of weed reduction were recorded at Primextra TZ Gold rates of 4.0-4.5 L/ha in combination with Elumis at 1.75-2.0 L/ha. Differences in weed infestation of phytocoenoses among hybrids were established, in particular higher values in the hybrid SY Fortago compared with SY Phenomen and SY Marimba. The combined use of Primextra TZ Gold (3.5-4.5 L/ha) and Elumis (1.75-2.0 L/ha) ensured effectiveness at the level of 94-98% control of grass and broadleaf weeds in crops of maize hybrids. The combined application of Primextra TZ Gold (4.0 L/ha) and Elumis (1.75 L/ha) ensured the maximum grain yield of the maize hybrids SY Phenomen (9.82 t/ha) and SY Marimba (10.08 t/ha). The highest productivity of the hybrid SY Fortago (9.16 t/ha) was ensured by applying the combination of Primextra TZ Gold (4.0 L/ha) and Elumis (1.5 L/ha). The obtained results could be used to develop and scientifically substantiate effective strategies for the control of segetal plants in

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maize phytocoenoses aimed at reducing weed infestation during the critical period of crop development and ensuring the sustainable functioning of agroecosystems

Keywords: agrocenosis; segetal vegetation; grain yield; synergism; ecological sustainability; herbicide load; control strategy

INTRODUCTION

Maize belongs to agricultural crops with low competitive ability against weeds, especially at the early stages of growth and development. In the period from emergence to the formation of 5-7 leaves, maize plants were characterised by slow growth rates, weak development of the root system, and insufficient canopy closure, which created favourable conditions for the intensive development of segetal vegetation. Under such conditions, weeds more effectively used moisture, nutrients, and light, thereby suppressing the growth and development of crop plants. The most negative impact of weeds on maize yield formation was observed during the critical period of competition, which occurred at the stages from 3-4 to 8-10 leaves. Weed infestation of crops during this period led to suppression of growth processes, a reduction in the assimilating surface area, and disturbances in the formation of generative organs, which caused a substantial decrease in the potential productivity of the crop (Anand *et al.*, 2025). Even short-term competition with weeds during the critical period of maize development could lead to a significant yield reduction that was not compensated in subsequent phases of plant growth and development, even after the complete removal of the weed component. In this regard, timely and effective control of weed infestation at the early stages of vegetation was a decisive factor in realising the genetic potential of maize productivity.

Weeds compete with crop plants for light, moisture, and nutrients, suppress their growth and development, and worsen the phytosanitary condition of crops, which resulted in a reduction in yield and product quality (Gersko *et al.*, 2024; Hurmanchuk *et al.*, 2025). According to R. Absy (2019), R. Idziak *et al.* (2022), weed infestation of maize crops led to a reduction in grain yield from 30 to 93% depending on the weather conditions in the years of research. It was established that the combined application of a mixture of terbuthylazine, mesotrione, and S-metolachlor provided the highest effectiveness of weed control and promoted stable formation of grain yield. According to the researchers R. Idziak & Z. Woznica (2020), effective control of a wide spectrum of weeds was ensured by the use of combined herbicides containing several active substances with different mechanisms. The use of such products made it possible to minimise crop injury due to lower doses and reduced chemical residues in plants and soil. In addition, the use of a combination of herbicides with different mechanisms of action slowed the development of resistant weed species and simultaneously reduced costs for plant protection.

In the work of Yu. Skatula & R. Ostapchuk (2023), the effectiveness of herbicide application in maize agrocenoses and their impact on the level of weed infestation of crops was highlighted. The effects of different herbicide protection schemes on the formation of the weed component and crop productivity were analysed. The expediency of using herbicides to reduce competition with segetal vegetation and to increase the efficiency of maize cultivation was established. According to R. Hutianskyi & V. Zuza (2022), herbicide application substantially reduced weed infestation (by 61-65% and 80%), improved plant growth and development, and ensured an increase in maize grain yield by 2.72 t/ha under the conditions of the Eastern Forest-Steppe of Ukraine. In the study by V. Yukhymuk *et al.* (2022), the features of interaction and the effectiveness of weed control in maize crops under the use of herbicide tank mixtures were investigated. The authors found that combining active substances with different mechanisms of action increased the level of control of segetal vegetation and ensured the stability of herbicide protection of the crop.

In the study by O. Gurmanchuk *et al.* (2020), the effectiveness of post-emergence herbicides (rimsulfuron, 250 g/kg, and florasulam 6.25 g/L + 2-ethylhexyl ester of 2,4-D 452.5 g/L) and their tank mixtures for regulating the presence of segetal plants in maize crops was evaluated. It was established that separate application of herbicides reduced weed infestation by 47.5-56.1%, whereas their mixtures reduced weed infestation by 92.5%. This ensured the maximum maize yield of 5.7 t/ha, which exceeded the control without herbicides by 3.0 t/ha. According to S. Shevchenko *et al.* (2025), the combination of nicosulfuron (40 g/ha) with 2,4-D and florasulam ensured a reduction in the number of annual weed species by 91%. Y. Tkalic *et al.* (2023) emphasised that effective weed control during the critical period of yield formation substantially reduced competition for resources and thereby contributed to higher maize productivity. The studies by N. Shokalo & V. Beletskyi (2022) also noted that post-emergence herbicides provided high effectiveness of weed control and positively affected yield under conditions of a mixed type of weed infestation.

In this regard, studies on the effectiveness of modern herbicides and the assessment of their influence on maize yield formation became important, which was a key factor in increasing agroecosystem productivity, strengthening food security, and implementing the principles of sustainable agricultural development.

Therefore, the purpose of the study was to evaluate the effectiveness of herbicide application for regulating the weed component in the maize phytocoenosis and its impact on crop yield formation.

MATERIALS AND METHODS

Field research was conducted during 2024-2025 under the conditions of the experimental field of Birytshechenko LLC, located in Raduly village, Zviahel district, Zhytomyr region. The soil of the experimental plots was soddy medium-podzolic and was characterised by the following indicators: humus content (according to Tiurin and Kononova (DSTU 7855:2015, 2016)) – 2.5%; easily hydrolysable nitrogen (according to Kornfield (DSTU 7863:2015, 2016)) – 63-79 mg/kg of soil; mobile phosphorus (according to Chirikov (DSTU 4115-2002, 2003)) – 74-85 mg/kg of soil; exchangeable potassium (according to Chirikov (DSTU 4115-2002, 2003)) – 83-92 mg/kg of soil; pH_{col} – 5.6-5.9 (DSTU ISO 10390:2021, 2022). The climate of the region where the research was conducted was temperate continental, with a cool winter and a moderately warm summer. Winters were characterised by frosts and an average temperature below 0°C. The average winter temperature (December-February) ranged within -1 to -5°C, with mean minimum values of about -6 to -8°C in the coldest months. The average temperature in the summer months varied within +18...+25°C. The mean annual precipitation amounted to 530-600 mm. Precipitation was distributed throughout the year, with a maximum in the summer months. Weather conditions during the maize vegetation periods differed from long-term averages. The experimental design included the following factors:

- Factor A – maize hybrid (SY Phenomen FAO 220, SY Marimba FAO 240, SY Fortago FAO 260);

- Factor B – application of a soil herbicide at different rates (control without treatment; Primextra TZ Gold 500 SC at 3.5 L/ha; Primextra TZ Gold 500 SC at 4.0 L/ha; Primextra TZ Gold 500 SC at 4.5 L/ha);

- Factor C – application of a post-emergence herbicide at different rates (control without treatment; Elumis 105 OD at 1.5 L/ha; Elumis 105 OD at 1.75 L/ha; Elumis 105 OD at 2.0 L/ha).

Primextra TZ Gold 500 SC is a combined soil herbicide of selective systemic action intended for effective control of the main annual grass and broadleaf weeds in the phytocoenoses of agricultural crops. It combined two active substances with different mechanisms of action: S-metolachlor (312.5 g/L) and terbuthylazine (187.5 g/L). S-metolachlor blocked cell division in young seedlings, while terbuthylazine suppressed photosynthetic processes, which led to weed death before emergence or immediately after crop emergence.

Elumis 105 OD is a selective systemic post-emergence herbicide intended to control a wide spectrum of annual and perennial grass and broadleaf weeds in

maize crops. Developed and produced by Syngenta, the product combined two active substances with different biochemical mechanisms of action: mesotrione (75 g/L) and nicosulfuron (30 g/L). The product had systemic action; therefore, after application to weed leaves, active molecules penetrated tissues, moved via xylem and phloem, and blocked key metabolic processes. Mesotrione inhibited carotenoid biosynthesis, which resulted in chlorophyll degradation, chlorosis, and tissue necrosis. Nicosulfuron inhibited amino acid synthesis by blocking enzymes involved in acetolactate synthase synthesis, which prevented normal growth and cell division in meristematic tissues of weeds. This combination made it possible to integrate a rapid foliar effect with prolonged systemic suppression of segetal plants. Elumis effectively prevented the emergence of several weed flushes during the vegetation period and reduced competition with the crop for resources. The studied products were developed and produced by Syngenta Ukraine.

The plot size was 100 m². The experiment had four replications, and plot arrangement was systematic. The maize cultivation technology was generally accepted for the research zone. Soybean was the preceding crop. Primary tillage involved ploughing with a Kverneland RN 100 plough to a depth of 25-27 cm, followed by pre-sowing cultivation with a Case IH Tiger-Mate 255 cultivator to a depth of 6-8 cm. Sowing of maize hybrids was carried out in the third ten-day period of April using a Kverneland Optima TF Profi planter with a target stand density of 80 thousand plants per 1 hectare. The soil herbicide Primextra TZ Gold 500 SC was applied immediately after sowing. Post-emergence application of the herbicide Elumis 105 OD was carried out at the 4-5-leaf stage of maize (the third ten-day period of May) using a Berthoud Raptor 4240 sprayer equipped with injector twin-fan nozzles. The working solution rate was 250 L/ha.

The study used a field method to assess the effect of herbicides on weed infestation and maize yield; an accounting method to determine weed density on experimental plots; a gravimetric method to determine crop yield indicators; and a mathematical-statistical method to process and interpret the obtained experimental data. During the vegetation period, phenological observations of maize plant growth and development were carried out. Herbicide phytotoxicity was assessed using a 9-point scale, where 1 point corresponded to complete plant death and 9 points corresponded to the absence of visual damage symptoms. On accounting plots with an area of 10 m², the total number of segetal plants and their numbers by groups were recorded and compared with the untreated control. The species composition of weed plant communities in the maize phytocoenosis was determined using generally accepted methods with the use of identification guides, atlases, and reference materials (Veselovsky *et al.*, 1988). The effectiveness of herbicide action was calculated before

harvesting. The effectiveness of herbicide application was assessed by analysing the accounting results and comparing them with the control variant in which herbicide treatment was not performed. The effectiveness of herbicide action in maize crops was calculated using a widely known formula. The authors adhered to the standards of the Convention on Biological Diversity (1992) and the Convention on International Trade in Endangered Species of Wild Fauna and Flora (1979). Mathematical processing of the research results was performed by analysis of variance and correlation–regression analysis on a personal computer using specialised application software packages such as MS Excel.

RESULTS

The use of soil and post-emergence herbicides enabled the control of a wide spectrum of annual and perennial grass and broadleaf weeds, ensuring crop protection during the critical period of its growth. Timely application of herbicides contributed to the formation of an optimal phytosanitary situation, reduced weed competition with maize plants, and increased the efficiency of moisture and nutrient use. The results of weed counts before harvest indicated a substantial dependence of herbicide protection effectiveness on the application rate of the product and the characteristics of the maize hybrid (Table 1).

Table 1. Weed infestation of the maize phytocoenosis depending on the timing and application rates of herbicides, mean for 2024-2025

Hybrid (Factor A)	Pre-emergence application of Primextra TZ Gold 500 SC, CS, L/ha (Factor B)	Post-emergence application of Elumis 105 OD, MD, L/ha (Factor C)	Number of weeds, plants/m ²		
			grass	broadleaf	total
SY Phenomen	Control	–	18.5	22.3	40.8
	3.5	Control	3.2	8.7	11.9
	4.0	Control	2.8	7.5	10.3
	4.5	Control	2.5	6.9	9.4
	3.5	1.5	0.8	1.5	2.3
	3.5	1.75	0.5	1.2	1.7
	3.5	2.0	0.3	1.0	1.3
	4.0	1.5	0.6	1.3	1.9
	4.0	1.75	0.4	1.0	1.4
	4.0	2.0	0.2	0.8	1.0
	4.5	1.5	0.7	1.4	2.1
	4.5	1.75	0.5	1.1	1.6
	4.5	2.0	0.3	0.9	1.2
	SY Marimba	Control	–	16.2	20.1
3.5		Control	2.9	7.8	10.7
4.0		Control	2.5	6.7	9.2
4.5		Control	2.2	6.1	8.3
3.5		1.5	0.7	1.3	2.0
3.5		1.75	0.4	1.0	1.4
3.5		2.0	0.2	0.8	1.0
4.0		1.5	0.5	1.1	1.6
4.0		1.75	0.3	0.8	1.1
4.0		2.0	0.1	0.6	0.7
4.5		1.5	0.6	1.2	1.8
4.5		1.75	0.4	0.9	1.3
4.5		2.0	0.2	0.7	0.9
SY Fortago		Control	–	20.1	25.5
	3.5	Control	3.5	9.5	13.0
	4.0	Control	3.0	8.2	11.2
	4.5	Control	2.7	7.6	10.3
	3.5	1.5	0.9	1.7	2.6
	3.5	1.75	0.6	1.4	2.0
	3.5	2.0	0.4	1.2	1.6
	4.0	1.5	0.7	1.5	2.2
	4.0	1.75	0.5	1.2	1.7
	4.0	2.0	0.3	1.0	1.3
	4.5	1.5	0.8	1.6	2.4
	4.5	1.75	0.6	1.3	1.9
	4.5	2.0	0.4	1.1	1.5

Source: compiled by the authors

In the control treatment, a high level of weed infestation of the crops was recorded, both by annual grass weeds (*Echinochloa crus-galli* L., *Setaria pumila* (Poir.) Roem. & Schult.) and by annual broadleaf weeds (*Chenopodium album* L., *Amaranthus retroflexus* L., *Ambrosia artemisiifolia* L.). The results of weed density assessments in maize crops indicated a substantial effect of both the separate and the combined use of herbicides on the formation of the phytosanitary status of the agrocenosis. In the untreated control (without chemical protection), a high level of weed infestation was recorded, which depended on the maize hybrid and ranged from 36.3 plants/m² in the hybrid SY Marimba to 45.6 plants/m² in the hybrid SY Fortago. This indicated differences in the competitive ability of hybrids against weeds.

Pre-emergence application of Primextra TZ Gold at rates of 3.5, 4.0, and 4.5 L/ha ensured a substantial reduction in weed density compared with the control. At the same time, partial re-establishment of certain broadleaf weed species was observed during the vegetation period. Under this application approach, the number of annual grass weeds decreased more effectively, whereas the density of broadleaf species remained relatively higher, especially in the second half of vegetation. Increasing the rate of Primextra TZ Gold contributed to a reduction in the total number of weeds; however, the difference between the rates of 4.0 and 4.5 L/ha was minor. Post-emergence application of Elumis at the studied rates (1.5, 1.75, and 2.0 L/ha) ensured a substantial reduction in the density of both grass weeds and broadleaf weeds during the maize vegetation period. Increasing the application

rate from 1.5 to 2.0 L/ha contributed to higher effectiveness in controlling late-emerging weeds and to an expanded spectrum of susceptible species.

The highest level of herbicide protection effectiveness was ensured by combining pre-emergence application of Primextra TZ Gold with post-emergence application of Elumis. In this treatment, a sharp and statistically significant reduction in the density of both grass weeds and broadleaf weeds was observed ($p \leq 0.05$). The total number of weeds decreased to 0.7-1.5 plants/m² depending on the hybrid and the application rates, which indicated a synergistic action of the soil and post-emergence herbicides. With an increase in the post-emergence rate of Elumis from 1.5 to 2.0 L/ha, higher effectiveness in controlling late-emerging weeds and an expanded spectrum of controlled species were recorded, primarily among broadleaf weeds. At the same time, the combinations Primextra TZ Gold 4.0-4.5 L/ha with Elumis 1.75-2.0 L/ha proved to be optimal in terms of effectiveness and rational use. The analysis of the hybrid effect showed that the hybrid SY Marimba was characterised by the lowest level of weed infestation across all protection treatments, whereas in the crops of the hybrid SY Fortago a higher number of weeds was consistently recorded. This confirmed the expediency of considering hybrid-specific characteristics when developing the herbicide protection system for maize. The results of calculations of herbicide effectiveness for regulating the presence of the weed component in the agrocenosis of maize of different hybrids depending on the timing and application rates are presented in Table 2.

Table 2. Effectiveness of herbicide application in the maize phytocoenosis depending on the timing and application rates, mean for 2024-2025

Hybrid (Factor A)	Pre-emergence application of Primextra TZ Gold 500 SC, CS, L/ha (Factor B)	Post-emergence application of Elumis 105 OD, MD, L/ha (Factor C)	Number of weeds, plants/m ²		
			grass	broadleaf	total
SY Phenomen	Control	-	-	-	-
	3.5	Control	82.70	60.99	70.83
	4.0	Control	84.86	66.37	74.75
	4.5	Control	86.49	69.06	76.96
	3.5	1.5	95.68	93.27	94.36
	3.5	1.75	97.30	94.62	95.83
	3.5	2.0	98.38	95.52	96.81
	4.0	1.5	96.76	94.17	95.34
	4.0	1.75	97.84	95.52	96.57
	4.0	2.0	98.92	96.41	97.55
	4.5	1.5	96.22	93.72	94.85
	4.5	1.75	97.30	95.07	96.08
	4.5	2.0	98.38	95.96	97.06
SY Marimba	Cotrol	-	-	-	-
	3.5	Control	82.10	61.19	70.52
	4.0	Control	84.57	66.67	74.66
	4,5	Control	86.42	69.65	77.13
	3.5	1.5	95.68	93.53	94.49
	3.5	1.75	97.53	95.02	96.14
	3.5	2.0	98.77	96.02	97.25

Table 2. Continued

Hybrid (Factor A)	Pre-emergence application of Primextra TZ Gold 500 SC, CS, L/ha (Factor B)	Post-emergence application of Elumis 105 OD, MD, L/ha (Factor C)	Number of weeds, plants/m ²		
			grass	broadleaf	total
SY Marimba	4.0	1.5	96.91	94.53	95.59
	4.0	1.75	98.15	96.02	96.97
	4.0	2.0	99.38	97.01	98.07
	4.5	1.5	96.30	94.03	95.04
	4.5	1.75	97.53	95.52	96.42
	4.5	2.0	98.77	96.52	97.52
SY Fortago	Control	–	–	–	–
	3.5	Control	82.59	62.75	71.65
	4.0	Control	85.07	67.84	75.60
	4.5	Control	86.57	70.20	77.58
	3.5	1.5	95.52	93.33	94.51
	3.5	1.75	97.01	94.51	95.82
	3.5	2.0	98.01	95.29	96.70
	4.0	1.5	96.52	94.12	95.38
	4.0	1.75	97.51	95.29	96.48
	4.0	2.0	98.51	96.08	97.36
	4.5	1.5	96.02	93.73	94.95
	4.5	1.75	97.01	94.90	96.04
	4.5	2.0	98.01	95.69	96.92

Source: compiled by the authors

Pre-emergence application of Primextra TZ Gold ensured a high level of weed control in the maize agrosystem; in particular, the effectiveness of control of annual grass weeds ranged from 82.1 to 86.57%, whereas that of broadleaf weeds ranged from 60.99 to 70.2%. Increasing the application rate from 3.5 to 4.5 L/ha led to a gradual increase in control effectiveness, especially for broadleaf species. Post-emergence application of Elumis markedly increased the effectiveness of weed control in the phytocoenoses of all studied hybrids. In combination with pre-emergence application of Primextra TZ Gold, the effectiveness of control of grass weeds reached 98-99%, broadleaf weeds 95-97%, and overall effectiveness amounted to 94-98%. The highest values were observed at the Elumis rate of 2.0 L/ha. Combined application of the products (pre-emergence + post-emergence) demonstrated a synergistic effect, ensuring the maximum possible level of weed control,

including late-emerging flushes and a broad spectrum of species. This confirmed the expediency of an integrated approach to herbicide protection in maize to ensure the ecological sustainability of agricultural systems.

The highest herbicide effectiveness for weed control at the same application rates and timing was recorded in the hybrid SY Marimba, whereas the lowest was recorded in SY Fortago, which indicated differences in the competitive ability of plants against weeds and the need for a differentiated approach to selecting herbicide rates. Maximum weed control was achieved with the combination of Primextra TZ Gold 4.0-4.5 L/ha and Elumis 1.75-2.0 L/ha, which ensured a 96-98% reduction in total weed density in maize crops regardless of the hybrid. Application of the herbicides Primextra TZ Gold and Elumis ensured an increase in grain yield of the maize hybrids SY Phenomen, SY Marimba, and SY Fortago (Table 3).

Table 3. Productivity of maize hybrids depending on the timing and application rates of herbicides (mean for 2024-2025)

Hybrid (Factor A)	Pre-emergence application of Primextra TZ Gold 500 SC, CS, L/ha (Factor B)	Post-emergence application of Elumis 105 OD, MD, L/ha (Factor C)	Yield, t/ha	Increase relative to the control	
				t/ha	%
SY Phenomen	Control	–	4.85	–	–
	3.5	Control	8.52	3.67	75.67
	4.0	Control	8.79	3.94	46.24
	4.5	Control	8.65	4.36	49.60
	3.5	1.5	9.21	4.36	50.40
	3.5	1.75	9.48	4.63	50.27
	3.5	2.0	9.35	4.5	47.47
	4.0	1.5	9.55	4.7	50.27
	4.0	1.75	9.82	4.97	52.04
	4.0	2.0	9.68	4.83	49.19

Table 3. Continued

Hybrid (Factor A)	Pre-emergence application of Primextra TZ Gold 500 SC, CS, L/ha (Factor B)	Post-emergence application of Elumis 105 OD, MD, L/ha (Factor C)	Yield, t/ha	Increase relative to the control	
				t/ha	%
SY Phenomen	4.5	1.5	9.42	4.57	47.21
	4.5	1.75	9.65	4.8	50.96
	4.5	2.0	9.51	4.66	48.29
SY Marimba	Control	-	5.21	-	-
	3.5	Control	8.93	3.72	71.40
	4.0	Control	9.17	3.96	76.01
	4.5	Control	9.05	3.84	73.70
	3.5	1.5	9.58	4.37	83.88
	3.5	1.75	9.79	4.58	87.91
	3.5	2.0	9.65	4.44	85.22
	4.0	1.5	9.85	4.64	89.06
	4.0	1.75	10.08	4.87	93.47
	4.0	2.0	9.92	4.71	90.40
	4.5	1.5	9.71	4.5	86.37
	4.5	1.75	9.95	4.74	90.98
	4.5	2.0	9.80	4.59	88.10
SY Fortago	Control	-	4.53	-	-
	3.5	Control	8.19	3.66	80.79
	4.0	Control	8.45	3.92	47.86
	4.5	Control	8.32	3.79	44.85
	3.5	1.5	8.87	4.34	52.16
	3.5	1.75	9.09	4.56	51.41
	3.5	2.0	8.95	4.42	48.62
	4.0	1.5	9.16	4.63	51.73
	4.0	1.75	9.02	4.49	49.02
	4.0	2.0	8.89	4.36	48.34
	4.5	1.5	9.03	4.5	50.62
	4.5	1.75	8.90	4.37	48.39
	4.5	2.0	8.77	4.24	47.64

Source: compiled by the authors

Pre-emergence application of Primextra TZ Gold had a substantial effect on maize yield. In the phytocoenoses of all maize hybrids, the use of the soil herbicide at application rates of 3.5, 4.0, and 4.5 L/ha ensured a grain yield increase of 3.66 to 4.36 t/ha compared with the control (without treatment), which amounted to 44.85-76.01%. Increasing the application rate of the product resulted in a slight increase in yield, especially in the hybrids SY Phenomen and SY Marimba. Post-emergence application of Elumis in combination with Primextra TZ Gold substantially increased grain yield. The highest increase was ensured by the hybrid SY Marimba, where, with the application of the combination Primextra 4.0 L/ha and Elumis 1.75 L/ha, the yield reached 10.08 t/ha, which exceeded the control by 93.47%. For the other hybrids, the yield increase under combined protection amounted to 47-52%.

Combined application of the soil and post-emergence herbicides ensured a synergistic effect, which contributed to a stable increase in grain yield of maize hybrids compared with treatments involving only pre-emergence application. This confirmed the expediency of an integrated approach to herbicide protection

in maize to maximise crop productivity. The highest grain yields were recorded in the hybrids SY Phenomen (9.82 t/ha) and SY Marimba (10.08 t/ha) under combined application of Primextra TZ Gold (4.0 L/ha) and Elumis (1.75 L/ha). The maximum grain yield of the hybrid SY Fortago (9.16 t/ha) was obtained with the application of the combination Primextra TZ Gold (4.0 L/ha) and Elumis (1.5 L/ha). Therefore, herbicide protection was an important element of the protection strategy and a necessary condition for effective maize cultivation. In addition, the rational use of modern combined herbicides, taking into account the species composition of weeds, crop development stages, and environmental conditions, made it possible to reduce the herbicide load on the agroecosystem, minimise negative environmental impacts, and ensure stable maize productivity.

DISCUSSION

The obtained results were consistent with Ukrainian and international studies, which reported that maize was one of the crops most sensitive to weed infestation during the first 30 to 40 days of vegetation, and that yield losses in the absence of effective weed

control could exceed 30 to 50% (Yoshitha *et al.*, 2025). The high level of weed infestation in the control treatments recorded in the experiment (36.3 to 45.6 plants/m²) corresponded to values reported by researchers who noted the dominance of annual grass weeds and broadleaf weeds in maize crops in the absence of herbicide protection (Gurmanchuk *et al.*, 2020). In the study by S. Okrushko (2019), it was indicated that soil herbicides effectively controlled annual grass weeds and early-emerging broadleaf species; however, their protective effect could weaken in the second half of vegetation, particularly under favourable conditions for repeated weed emergence. A similar tendency was also observed in this study, where, under separate pre-emergence application of Primextra TZ Gold, re-establishment of broadleaf weeds was noted, and increasing the product rate did not always ensure a proportional increase in effectiveness.

According to the findings of B. Wiqar *et al.* (2021), the most stable weed control in maize crops was achieved under an integrated use of soil and post-emergence herbicides. This was also supported by the results of the present research, where the combination of Primextra TZ Gold with post-emergence application of Elumis reduced total weed density to 0.7 to 1.5 plants/m². Similar effectiveness indicators were reported in studies devoted to the use of mesotrione and nicosulfuron for controlling both grass weeds and broadleaf weeds, including late-emerging flushes (Mitkov *et al.*, 2022). The literature also indicated that the level of weed infestation depended on the crop hybrid (Kryvulko, 2025). This was associated with differences in the intensity of early growth, leaf canopy architecture, and the competitive ability of plants. The differences identified in this study between hybrids, in particular the higher level of weed infestation in the crops of the hybrid SY Fortago compared with SY Phenomen and SY Marimba, fully agreed with these provisions and confirmed the need to adapt herbicide schemes to the biological characteristics of specific hybrids.

The obtained results regarding the effectiveness of herbicide weed control in maize crops were consistent with data reported in the literature. Thus, in field studies by V. Gurtovenko and O. Tsyuk (2024), the use of soil herbicides demonstrated a high level of weed suppression at the early stages of maize growth. The effectiveness of control of grass weeds and broadleaf weeds 14 days after application reached up to 87%, and after 40 days up to 75%, which corresponded to the present results, where pre-emergence application of the soil herbicide ensured a weed control level above 70% in the experimental treatments. The results of combined weed control, when post-emergence herbicides complemented the soil action of Primextra, were also supported by the study of S. Soroka (2025). In the studies by V. Sudak *et al.* (2021), it was noted that post-emergence products could provide high control effectiveness depending on

weed species composition and application conditions, and that maximum values were achieved when combined with soil products, which expanded the spectrum of controlled species and prolonged the duration of the protective effect.

The research by O. Milenko *et al.* (2022) on the effectiveness of Elumis 105 OD also emphasised its high efficacy in controlling both grass weeds and broadleaf weeds during the phase of active maize vegetation, particularly when applied at optimal timings, namely at the 2 to 8 leaf stages of the crop. This supported the observations regarding the high level of weed control in treatments with post-emergence herbicide application. Therefore, the obtained data not only corresponded to existing scientific sources regarding the high effectiveness of soil and post-emergence herbicides in maize protection systems, but also highlighted the practical expediency of the combined use of herbicides to achieve the maximum level of weed control, which was consistent with the recommendations of modern agronomic technologies (Sudak *et al.*, 2021).

The data of H. Alptekin *et al.* (2023) confirmed that weed control intensity and maize yield were closely related to the selected herbicide protection schemes, and that the use of herbicide combinations was effective for achieving consistently high yield levels, which supported the appropriateness of the schemes selected in this study. The findings obtained in the present experiment on the effect of herbicide protection on maize yield were consistent with the published study by M. Devkota *et al.* (2024), which confirmed the positive role of herbicides in increasing crop productivity. Thus, field experiments by O. Markovska *et al.* (2024) indicated that the application of soil and post-emergence herbicides substantially reduced above-ground weed biomass and contributed to a significant increase in grain yield in research where comprehensive herbicide protection schemes were applied. An increase in grain yield under the integrated use of soil and post-emergence protection was also observed in this study. Consequently, the results not only confirmed well-established regularities of herbicide weed control in maize crops, but also complemented the literature data regarding the expediency of the combined application of soil and post-emergence herbicides while taking into account hybrid-specific characteristics.

CONCLUSIONS

Post-emergence application of Elumis at rates of 1.5 to 2.0 L/ha significantly reduced the density of grass weeds and broadleaf weeds in maize crops ($p \leq 0.05$). Increasing the rate to 2.0 L/ha ensured more effective control of late-emerging weeds. Weed density assessments showed that combining pre-emergence application of Primextra TZ Gold (3.5 to 4.5 L/ha) with post-emergence application of Elumis (1.5 to 2.0 L/ha) ensured a substantial reduction in the total number of

grass weeds and broadleaf weeds in maize crops compared with the control ($p \leq 0.05$). The highest effectiveness of weed control was recorded under the combined use of the products at Primextra TZ Gold rates of 4.0 to 4.5 L/ha and Elumis rates of 1.75 to 2.0 L/ha, where weed density decreased to 0.7 to 1.5 plants/m². The effectiveness of herbicide protection varied depending on the maize hybrid; in the crops of the hybrid SY Fortago, a tendency towards higher weed infestation was recorded compared with the hybrids SY Phenomen and SY Marimba.

Pre-emergence application of Primextra TZ Gold (3.5 to 4.5 L/ha) ensured 71 to 77% effectiveness of weed control in maize crops. Its combination with the post-emergence herbicide Elumis (1.5 to 2.0 L/ha) increased effectiveness to 94 to 98%, ensuring control of both grass weeds and broadleaf weeds, including late-emerging flushes. The highest effectiveness was observed at the Elumis rate of 1.75 to 2.0 L/ha. The combined application of Primextra TZ Gold (4.0 to 4.5 L/ha) and Elumis (1.75 to 2.0 L/ha) ensured the formation

of the maximum grain yield of the maize hybrids SY Phenomen (9.82 t/ha) and SY Marimba (10.08 t/ha). The highest grain yield of the hybrid SY Fortago (9.16 t/ha) was obtained under the integrated application of Primextra TZ Gold (4.0 L/ha) and Elumis (1.5 L/ha). This highlighted the expediency of a differentiated approach to herbicide protection. Further research should be directed towards optimising herbicide protection technologies for maize, taking into account the species structure of segetal vegetation, soil and climatic conditions, and minimising the herbicide load, with the aim of forming resilient agrophytocoenoses.

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CONFLICT OF INTEREST

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Регулювання бур'янового компоненту у фітоценозі кукурудзи за використання гербіцидів для сталого функціонування агроєкосистем

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Анотація. Кукурудза є культурою з низькою конкурентною здатністю щодо бур'янів, особливо на ранніх етапах росту та розвитку. Проблема забур'яненості посівів кукурудзи у критичний період вегетації залишається одним із ключових факторів, призводить до істотного зниження реалізації потенціалу врожайності культури. Метою досліджень було оцінити ефективність застосування гербіцидів для регулювання бур'янового компоненту у фітоценозі кукурудзи та їх вплив на формування врожайності культури. Дослідження проводили протягом 2024-2025 рр. в умовах ТОВ «Біріт ім. Шевченка» Житомирської області на середньо підзолистих дернових ґрунтах. Висвітлено ефективність гербіцидів для регулювання сегетальної рослинності у фітоценозі трьох гібридів кукурудзи залежно від строків і норм внесення. Комбіноване застосування досходового гербіциду Примекстра TZ Голд та післясходового гербіциду Елюміс забезпечило зниження кількості злакових і дводольних бур'янів у фітоценозі кукурудзи. Найвищі показники зниження кількості бур'янів відмічено за норм Примекстра TZ Голд 4,0-4,5 л/га у поєднанні з Елюмісом 1,75-2,0 л/га. Встановлено відмінності забур'яненості фітоценозів різних гібридів, зокрема вищі показники у гібрида СИ Фортаго порівняно з СИ Феномен та СИ Марімба. Комбіноване застосування гербіцидів Примекстра TZ Голд (3,5-4,5 л/га) і Елюміс (1,75-2,0 л/га) забезпечило ефективність на рівні 94-98 % контролю злакових і дводольних бур'янів у посівах гібридів кукурудзи. Комбіноване застосування гербіцидів Примекстра TZ Голд (4,0 л/га) і Елюміс (1,75 л/га) забезпечило максимальну урожайність зерна кукурудзи гібридів СИ Феномен (9,82 т/га) і СИ Марімба (10,08 т/га). Найвищу продуктивність гібриду СИ Фортаго (9,16 т/га) забезпечило внесення комбінації Примекстра TZ Голд (4,0 л/га) і Елюміс (1,5 л/га). Отримані результати можуть бути використані для розробки та наукового обґрунтування ефективних стратегій контролю сегетальних рослин у фітоценозах кукурудзи, спрямованих на зниження рівня забур'яненості в критичний період розвитку культури та забезпеченню сталого функціонування агроєкосистем

Ключові слова: агроценоз; сегетальна рослинність; урожайність зерна; синергізм; екологічна стійкість; гербіцидне навантаження; стратегія контролю