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RESEARCH ARTICLE

Transformation of weed communities under the evolution of agricultural technologies

Serhii Shevchenko[1*], Oleksandr Mytsyk[1], Oleksandr Hulenko[1], Oleksandr Havriushenko[1], Yurii Rudakov[1], Vasyl Pozniak[1], Valentyn Sichevyi[1], Mykhailo Rumbakh[2], Kateryna Derevenets-Shevchenko[3], Mykhailo Shevchenko[4], Oleksandr Shevchenko[4]

[1]Department of General Agriculture and Soil Science, Dnipro State Agrarian and Economic University, Dnipro, Ukraine

[2]Department of Plant Science, Dnipro State Agrarian and Economic University, Dnipro, Ukraine

[3]Laboratory of Plant Protection, State Enterprise Institute of Grain Crops of the National Academy of Agrarian Sciences of Ukraine, Dnipro, Ukraine

[4]Laboratory of Agriculture and Soil Fertility, State Enterprise Institute of Grain Crops of the National Academy of Agrarian Sciences of Ukraine, Dnipro, Ukraine

***Corresponding author:** Serhii Shevchenko, Department of General Agriculture and Soil Science, Dnipro State Agrarian and Economic University, Dnipro, Ukraine, Email: shevchenko.s.m@dsau.dp.ua

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Abstract

The article analyzes the dynamics of weed species composition in the agrocenoses of the Ukrainian Steppe under technogenic pressure caused by changes in farming systems and herbicide load. It was established that technobiogenic transformation of agroecosystems induces associative variability in weed phytocoenoses, which is manifested in shifts of dominant species and their resistance to control measures. A historical and analytical survey of weed species composition was conducted using Raunkiaer's method for the period 1958-2025. An optimal agrotechnological model for weed management was proposed, taking into account crop structure, soil tillage methods, and herbicide application intensity.

Keywords: Winter wheat, Maize, Sunflower, Legumes, Soil, Weed, Tillage, Crop rotation, Herbicide

Introduction

The history of techno-botanical adaptation of weeds not only reveals the mechanisms behind the evolutionary dynamics of phytocoenotic species composition, but also accumulates an ecological database for developing synchronized forecasts regarding the type and degree of weed infestation, as well as the herbicide resistance profile of weed communities (Cherenkov, et al. 2021, Shevchenko, et al. 2025).

Weed species exhibit the highest evolutionary sensitivity to such agro-systemic factors as crop rotation schemes, phytocoenotic stability of cultivated crops, the application of herbicides with varying modes of action, and methods of mechanical impact on soil and weeds (Shevchenko, et al. 2024, Mytsyk, et al. 2025 and Gemtou, et al. 2025).

Given the relevance of targeted weed control in crop production, the aim of our research was to retrospectively trace the evolutionary pathways of weed phytocoenoses under technogenic pressure caused by herbicide use and primary soil tillage practices, to identify the directions and rates of species composition transformation, and to develop agrotechnological approaches for weed regulation and future-oriented weed management planning (Gupta, et al. 2025, Lidder, et al. 2025 and Jahanbakht, et al. 2025).

Materials and Methods

The main results of the research were obtained through long-term field experiments, surveys of production fields, and assessments of undisturbed natural habitats within the zone of steppe farming, based at the Experimental Station of the Institute of Grain Crops of NAAS and Dnipro State Agrarian and Economic University. The methodological monitoring period covered the development of agriculture from 1958 to 2025 and was divided into critical stages: 1958-1970 (data by O.V. Fisiunov), 1981-2002 (data by M.S. Shevchenko), and 2011-2025 (data by S.M. Shevchenko).

In this context, Raunkiaer's frequency index was used to build a continuous historical model for evaluating weed species composition and generating comparable datasets, as it provides insight into the frequency and distribution of individual species across landscapes. The assessment of the technico-economic level of each agricultural development stage was based on scientific publications, analytical reports, and statistical reviews.

Results and Discussion

Over the 67-year period of herbological observations and the study of weed development patterns in agricultural crop fields, a strong correlation was observed between agro-industrial land use systems and the nature of weed infestation in agrocenoses. A key objective in this context was to shift from visual assessments of the rotational changes in weed phytocoenoses to a methodologically grounded and digitized registration of technogenic evolutionary trends. This approach ensures a higher degree of reliability in recording biocoenotic parameters and offers strong reproducibility of research results over an extended phytomonitoring period (Tab. 1).

The agrotechnical period was characterized by minimal herbicide use (up to 25% of treated crops), limited prevalence of row crops (such as maize, sunflower, and sugar beet) in the cropping structure (23%), and a dominance of energy-intensive plowing, which was applied to 74% of arable land. Under this technological level of farming, the weed species most adapted to the prevailing ecological vacuum and competitive environment in agrocenoses included *Setaria glauca* (yellow foxtail), *Amaranthus albus* L. (white pigweed), *Chenopodium album* L. (common lambsquarters), and *Polygonum convolvulus* (black bindweed).

When these species had unrestricted access to ecological resources in black fallow fields, their frequency of occurrence reached a maximum (81%-90%). However, with the introduction of competitive pressure from maize crops, their presence in the phytocoenosis sharply declined to 96-5% (Tab. 2).

Table 1. Key elements of technobiogenic influence on the formation of weed phytocoenotic spectrum by stages of agricultural development.

Herbicides, percentage of treated area (%)	Herbicide effectiveness (%)			Crop structure (%)	Soil tillage method (percentage share %)
	Monocots	Dicots	Perennial		
Period 1958-1970 (Fisiunov O.V. data)					
2,4-D amine salt	0	75-82	74-80	Cereals and legumes-32	Moldboard plowing-74
Atrazine (atrazine)	78-85	80-86	45-53	Maize-7	Blade cultivation-15
Agrotechnical methods	68-77	74-83	60-70	Industrial crops-13 Forage crops-34	Surface tillage-11
Treated area-25%				Fallow-8 Other crops-6	
Period 1981–2002 (Shevchenko M.S. data)					
Atrazine (atrazine)	72-79	77-84	43-50	Cereals and legumes-34	Moldboard plowing-65
Dialen (2,4-D+dicamba)	0	80-90	83-88	Maize-9	Nonmoldboard-20
Acenit (acetochlor+AD-6)	80–86	83–88	0	Industrial crops-14	shallow tillage-15
Eradicane (S-ethyl dipropylthiocarbamate)	87-93	52-58	0	Forage crops-32	
Harness (acetochlor)	88-94	86-94	0	Fallow-8	
Treflan (trifluralin)	83-89	80-86	0	Other crops-3	
Roundup (glyphosate)	86-94	90-97	87-93		
Treated area-52%					

Period 2011–2025 (Shevchenko S.M. data)					
Adengo (isoxaflutole, thiencarbazone-methyl)	77-83	84-91	81-85	Cereals and legumes-40	Moldboard plowing-45
Esteron (2,4-D ethylhexyl ester)	0	81-89	82-87	Maize-15	Conservation tillage-25
MaisTer (foramsulfuron, iodosulfuron, thiencarbazone)	85-89	84-89	71-77	Industrial crops-35	shallow tillage-30
Basis (rimsulfuron, thifensulfuron-methyl)	80-85	84-90	69-74	Forage crops-4	
Task (dicamba, rimsulfuron)	78-86	84-88	77-82	fallow-4	
2,4-D amine salt	0	78-84	75-81	Other crops-2	
Treflan (trifluralin)	82-87	80-84	0		
Harness (acetochlor)	88-93	89-94	0		
Eurolightning (imazamox, imazapyr)	86-90	88-93	67-74		
Roundup (glyphosate)	85-96	88-97	86-92		
Treated area-76%					

Table 2. Development of agriculture and species variability of weeds in agrocenoses, % (Frequency of occurrence of individual species according to Raunkiaer's method).

No.	Weed species	Crop and observation periods								
		Black Fallow			Winter wheat			Maize		
		1958-1967	1989-1992	2014-2021	1958-1967	1989-1992	2014-2021	1958-1967	1989-1992	2014-2025
1	*Setaria glauca* (L.) P.Beauv.	98	69	37	8	5	2	96	15	11
2	*Echinochloa crus-galli* (L.) P.Beauv.	16	92	84	0	2	2	1	88	69
3	*Amaranthus retroflexus* L.	20	97	90	0	3	1	0	93	84
4	*Amaranthus albus* L.	94	31	22	3	1	0	85	7	6
5	*Amaranthus blitum* L.	2	36	20	0	0	0	0	23	14
6	*Chenopodium album* L.	89	30	27	10	4	3	72	17	15
7	*Polygonum convolvulus* L.	81	28	32	0	0	0	57	17	18
8	*Ambrosia artemisiifolia* L.	2	56	99	0	7	13	0	39	95
9	*Sisymbrium loeselii* L.	17	9	7	12	10	10	10	4	2
10	*Thlaspi arvense* L.	32	18	11	21	14	10	12	2	3
11	*Descurainia sophia* (L.) Webb ex Prantl	14	7	7	22	15	11	16	9	4
12	*Capsella bursa-pastoris* (L.) Medik.	28	20	13	23	15	8	13	9	7
13	*Cirsium arvense* (L.) Scop.	34	15	9	24	13	8	28	11	6
14	*Sonchus arvensis* L.	30	17	3	21	11	4	24	12	8
15	*Convolvulus arvensis* L.	30	14	3	17	9	2	19	8	5
16	Rare species	6	4	2	4	2	1	5	3	2

An ecologically and economically balanced system of effective weed control should be based on the following technobiogenic parameters: the share of row crops in crop rotation should not exceed 35%-38%; herbicide use in row crop fields should remain within 75%-85%; solid seeding methods should be applied on 55%-60% of cropland; plowing should cover 20%-25% of the area; No-till practices should account for 10%-15%; and 60%-70% of fields should utilize other soil tillage minimization techniques.

Conclusion

It has been established that the technogenic evolution of agriculture, driven by changes in tillage systems, crop rotation structure, and herbicide pressure, significantly influences the species composition of weeds in the agrocenoses of the Ukrainian Steppe.

Weeds exhibit high associative variability and adaptability, modifying their presence depending on the cultivated crop, agrotechnical practices, and level of chemical input.

To achieve ecologically and economically balanced weed control, it is advisable to implement an agrotechnological model that integrates limited herbicide use, crop diversity in rotations, partial retention of traditional plowing, and the development of minimal tillage systems.

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Disclosure statement

No potential conflict of interest was reported by the author(s).

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