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Original article

Environmental risks in agrophytocoenoses under the influence of segetal phytobiota

Alla M. Lishchuk[1], Alla I. Parfenyk[1], Nadiya V. Karachinska[1]*, Natalia M. Topchii[2]

[1] Institute of Agroecology and Environmental Management, National Academy of Agrarian Sciences of Ukraine, 12 Metrologichna Str., Kyiv, 03143, Ukraine

[2] Berkeley City College, Berkeley, California, The United States of America

*E–mail address (*corresponding author): karachinskan051177@gmail.com*

ORCID iD: Alla M. Lishchuk: https://orcid.org/0000-0002-8339-9365; Alla I. Parfenyk: https://orcid.org/0000-0003-0169-4262; Nadiya V. Karachinska: https://orcid.org/0000-0002-6571-8430; Natalia M. Topchii: https://orcid.org/0009-0009-3864-1456

ABSTRACT

In this article the influence of abiotic factors on agrophytocoenoses is considered, these are: moisture supply, rising air temperature, increasing carbon dioxide concentration, and the probability of environmental risks in particular. The degree of ecological risk has been established. Environmental risks due to the influence of climate change on agrophytocoenoses have been identified and substantiated and are: the spread of adventive and invasive plant species; loss of competitiveness of agrophytocoenosis crops relative to segetal phytobiota; increase in the number of species and distribution areas of segetal phytobiota; change in the sown area, productivity and quality of the harvest of agricultural crops; acquisition of tolerance of segetal phytobiota of agrocoenoses to herbicides and deterioration of their effectiveness under agroclimatic fluctuations. All of the above-mentioned environmental risks, which are associated with aggravation of the phytosanitary condition of crops inevitably, lead to a loss of the productivity of agrocoenoses. They lead to a decrease in the quality of the obtained plant and agricultural products as well. Along with the loss of productivity of the weedy agrocoenosis, there are environmental risks caused by the increased need for the use of plant protection products to ensure the control of the phytosanitary state of the agrocoenosis. Ensuring the reduction of environmental risks and enhancing the ecological safety of agrocoenoses is timely environmental monitoring, considering appropriate agronomic, protective, and preventive measures. These measures increase the adaptive capacity of agrocoenoses. r atmospheric levels in analyzing pertinent cases.

KEY WORDS: ecological risks, weeds, ecological factors, herbicides, climate changes

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1. Introduction

Environmental factors contribute to the emergence of environmental risks in agrophytocoenoses. Most environmental risks have a complex character, as they are caused by the simultaneous influence of several environmental factors, which are namely: abiotic, biotic and anthropogenic. These factors mostly overlap and act together, which leads to the strengthening, or weakening, of their negative impact on the environment. Therefore, their influence should be considered both separately and comprehensively. The negative impact of environmental factors contributes to the deterioration of the phytosanitary condition, which is expressed by: loss of soil fertility and crop productivity; contamination of the agrocoenosis with infectious grains, residues of fertilizers and plant protection products; harmful effects on human health and the ecological condition of agro-ecosystems.

Quantitative and qualitative assessment of environmental risks posing a threat to an agrocoenosis depends on many factors, for example: on the type

of culture and variety cultivated in the affected area; quantity and quality of environmental factors; soil and climatic conditions and prospects of the agro-climatic zone. The consequences of the negative impact of an ecological factor in an agrocoenosis are evaluated: qualitatively – by the manifestation of risk; quantitatively – by value in monetary equivalent to establish the expediency of carrying out timely agrotechnical measures for the care and control of the phytosanitary condition of agrocoenoses.

Abiotic factors responsible for global climate changes are an integral ecosystem component, including agrophytocoenoses. Their impact on agrophytocoenoses is often beyond human control and can sometimes reach a physiological limit that causes stress in cultivated plants. In Ukraine, the influence of abiotic factors (air temperature, precipitation) that fluctuate under climate change conditions on the physiology of cultivated plant varieties has been sufficiently studied. These problems were investigated and presented in numerous scientific works (Borzykh et al., 2015; Mostovyak & Demyanuk, 2020; Pysarenko et al., 2019; Ivashchenko et al., 2017; Zatula & Zatula, 2020; Kokhan et al., 2020). Among the foreign scientists who studied the impact of climate change on the spread of weeds and their adaptation to fluctuating air temperature and soil moisture, are: Anwar et al., 2021; Malarkodi et al., 2017; Matzrafi et al., 2016; Howden et al., 2007; Olson et al., 2000.

Some scientists have proven that the appropriate reaction in the form of dynamic homeostasis occurs in the phytobiota of agrocoenoses at the level of the cell, tissue, and plant structures. Manifestation of plant reactions to abiotic stress depends on such factors as: degree of severity and duration of stress, period of ontogenesis and genetic features of the crop variety (Kiriziy & Stasyk, 2022). Environmental factors under the influence of climatic changes can cause uncertainty in the implementation of timely agrotechnical measures for the care and control of the phytosanitary state of agrocoenoses.

Analysis of the different domestic and foreign scientific publications and our results showed that the greatest danger of environmental risks in agrophyto-coenoses is caused by the long-term impact of global climate changes on the ecosystem (Mostovyak & Demyanuk, 2020; Kiriziy & Stasyk, 2022; Lishchuk et al., 2022, 2023; Moklyachuk et al., 2020). Under these conditions, the problems of the spread of weeds and invasive alien plants in agroecosystems increase and, as a result, their habitats and population density change. However, studies of the peculiarities of ecological risks in agrophytocoenoses under the negative influence of environmental factors in the conditions of climate change, which cause changes in the dynamics and species composition of segetal vegetation, remain poorly studied. After all, the deterioration of the phytosanitary situation in agrophytocoenoses is primarily the root cause of a decrease in their productivity, a decrease in the quantity and quality of the harvest and, ultimately, is reflected in the spread of degradation processes in the agrosphere.

The purpose of this work was to assess the influence of abiotic factors such as air temperature, humidity, and increased carbon dioxide concentration, on the distribution and species composition of segetal vegetation of agrophytocoenoses and to substantiate the likelihood of environmental risks.

2. Materials and methods

During our research comparative and practical analysis of scientific publications have been used to organize thematic issues. The assessment of phytobiota in agrocoenoses was conducted based on the species diversity of vegetative weeds. The names of plants are provided in accordance with the nomenclature list (Mosyakin et al., 1999; Kosolap et al., 2022). The scale of gradation for assessing ecological risks in agrophytocoenoses was developed using the degree of weed infestation (Stankevich et al., 2021). The ecological risks of the impact of agroclimatic conditions on changes in the sown areas of agricultural lands in Ukraine when cultivating major crops were studied for the period from 2000 to 2020. Data from the State Statistics of Ukraine were used for this purpose (Verner, 2021). With the help of an empirical and systematic approach, the mutual dependence of the occurrence of environmental risks under the influence of changes in agroclimatic conditions on the segetal phytobiota of agrophytocoenoses was revealed.

3. Results and discussion

3.1. Ecological risks of deterioration of the phyto-sanitary state of agrocoenoses under the influence of abiotic factors – air temperature and soil moisture

Intensive agricultural technologies contribute to the emergence and spread of new types of weeds, pathogens of plant diseases and pests in agroecosystems, which quickly adapt to new conditions against the background of global climate change. According to

scientific publications (BORZYKH ET AL., 2015; MOSTOVYAK & DEMYANUK, 2020; PARFENYK & VOLOSHCHUK, 2016), we have identified a list of environmental risks associated with the deterioration of the phytosanitary state of agrocoenoses in the territory of Ukraine under the influence of abiotic factors (air temperature and soil moisture), which lead to a decrease in the quality and yield of agricultural products. Among such risks, the following are highlighted: a change in the habitats of harmful organisms and their spread to the north; an increase in the number of types of harmful organisms; emergence of new types of weeds, pests and pathogens; increasing the degree of damage to cultivated plants; a decrease in the effectiveness of the use of phytosanitary measures; increasing the ecological threshold of harmfulness organisms (Fig. 1).

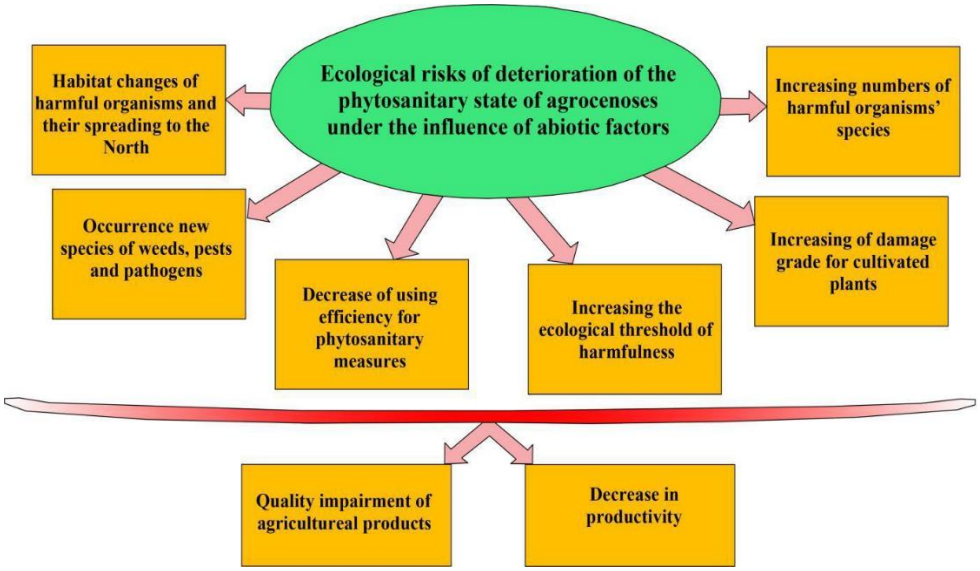


Fig. 1. Ecological risks of deterioration of the phytosanitary state of agrocoenoses under the influence of the abiotic factors of air temperature and soil moisture (Source: own research)

Strengthening the mentioned environmental risks against the backdrop of climate change can be contributed by non-compliance with crop rotations and environmental standards, which leads to the unsatisfactory ecological condition of agricultural land. To assess the occurrence of environmental risks in agrocoenoses, complex ecological monitoring is carried out, consisting of separate monitoring components with corresponding directions, criteria, and parameters.

3.2. Phytobiotic monitoring in agrophytocoenoses to identify environmental risks

In agrophytocoenoses, to determine the species composition, vegetation cover, and various levels of phytobiota structure, phytobiotic monitoring is employed (MUDRAK & MUDRAK, 2019). A number of methods are used to identify environmental risks caused by the biological invasion of weeds into agrocoenoses which are influenced by abiotic climate change factors. In particular, here are the methods of surveying crops that determine the level of weediness in the following indicators: the number of weeds; projected covering of the soil surface with weeds; mass of weeds; the ratio of the number of cultivated plants to weeds in agrophytocoenoses. Depending on the level of weediness in agrocoenoses of agricultural crops, different thresholds of harmfulness are distinguished: phytocoenotic, practical, economic (SHUVAR ET AL., 2011; STANKEVICH ET AL., 2021).

Weeds, as a component of agrophytocoenoses, enter into a competitive interaction with cultivated plants and lead to the emergence of environmental risks. When assessing the impact of segetal vegetation on the formation of ecological risks in agrocoenoses, it is necessary to take into account the types of diversity of segetal weeds that invade crops, and the ecological features of their harmful effects. In this regard, the our work involved assessing the occurrence of ecological risk in agrophytocoenoses of agricultural crops.

Based on the generalized results of the analysis of commonly used methods for determining the level of weediness of agrophytocoenoses, we developed a 5-level gradation scale for assessing the occurrence of ecological risks under the influence of segetal phytobiota

(Table 1). The developed scale considers such indicators as the degree of weediness by annual and perennial weed species and by the number of weed seeds.

The proposed gradation is based on the classification of environmental risks according to the degree of their growth (ecological disadvantage) and includes a 5-level evaluation scale of indicators that reflect quantitative or qualitative manifestations of risks of damage (or degradation) of agrocoenoses from 0 to 4 points, which correspond to a certain risk assessment: 0 points – no risk insignificant and indicates the most favourable conditions in the agrocoenosis for ensuring balance, stability and ecological safety of the agrocoenosis, 1 point – minor, 2 points – moderate, 3 points – significant, 4 points – critical risk – indicates a low level of sustainability of the agrocoenosis.

Table 1. Gradation scale for an ecological risk assessment of agrophytocoenoses according to the degree of weediness (Source: Modified by the authors according to published data, Stankevich et al., 2021)

Weediness of agrophytocoenoses by agrobiological subtypes of weeds, quantity/m²		Number of weed seeds, million numbers/hectare	Level of risk	
Perennial	Annual		Risk score	Category
1–20	0.1–0.5	0	0	Insignificant
20–50	0.5–3	< 5	1	Minor
50–100	3–5	5.1–10	2	Moderate
100–150	5–10	10.1–50	3	Significant
>150	>10	50.1–100	4	Critical

It is known that the majority of adventive weed species are segetal, or ruderal plants, among thesethere are predominantly unknowingly introduced species (acolyutophytes), which are an ecological threat to agrophytocoenoses.

On the territory of Ukraine, the deterioration process of the phytosanitary status of agrophytocoenoses is progressing against the background of rapid agroclimatic changes, and this requires constant phytobiotic control to prevent the occurrence of ecological risks.

3.3. Ecological risks of the spread of adventive and invasive plant species in agrophytocoenoses

The problem of the spread of non-native plant species (adventive, alien, unnatural) in new territories, including phytoinvasion, is recognized as a problem that threatens the biodiversity of the environment. Recently, the penetration and spread of biogeographically foreign invasive species into the local phytobiota often turns out to be a common phenomenon in agrocoenoses. As evidenced by the analysis of foreign and domestic sources of literature, biological invasion is considered to be one of the main worldwide environmental problems (Burda et al., 2015; Galappaththi et al., 2023), which is associated with the penetration and spread of non-native species of phytobiota.

Invasive phytobiota has a significant impact on local agrocoenoses and ecosystems. In Ukraine, there are more than 3,500 plant species among wild phytocoenoses, of which about 700 can occur as segetal or field weeds in ecosystems and agrocoenoses of fields, gardens, orchards (Tkach et al., 2018). It is common knowledge that modern climate changes in Ukraine are moving towards warming, aridity and changes in the hydrothermal conditions of the natural environment. Scientists of the National Academy of Sciences of Ukraine have established a trend of actual displacement of the borders of the natural and climatic zones of Ukraine of upto 100–150 km to the north, which have been observed for the last decades (Zatula & Zatula, 2020). This helps to change the distribution areas of various types of weeds. Research by scientists found that under the influence of climate change there is a redistribution of the species composition of the phytobiota and a disruption of the structure of natural ecosystems (Protopopov & Shever, 2019).

It is known that each agro-climatic zone is characterized by a complex of segetal phytobiota, but with a change in hydroclimatic conditions, the spread and high acclimatization of the secondary range of invasive species from their inherent agro-climatic zones occurs (Ramesh et al., 2017). The hydrothermal indicators in the astroclimatic subzone of the Northern Steppe (Dnipropetrovsk, Kirovohrad regions) already correspond to the subzone of the Southern Steppe. At the same time, the agro-climatic subzone of the Northern Steppe is gradually moving into the Forest Steppe zone, namely to the territory of Cherkasy,

Poltava and other regions. In particular, the authors claim that in the Northern latitudes, mild winters can contribute to the survival of overwintering weed species and the intensive growth of summer annual weeds under the influence of high summer temperatures (PYSARENKO ET AL., 2019).

As a consequence of climate change in the Steppe the vegetation began to change, and because of parasitic weed species are spreading, such as: creeping mustard (*Acroptilon repens* L.), european snakeroot (*Aristolochia clematitis* L.), buffalo bur *(Solanum rostratum* Dunal.), johnsongrass (*Sorghum halepense* (L.) Pers.), ragweed (*Ambrosia artemisiifolia* L.), all types of orobanchaceae (*Orobanch*e L.) and godder (*Cuscuta* sp.) (IVASHCHENKO ET AL., 2017). At the same time, the distribution areas of weeds, which are traditionally strong competitors for water, especially in conditions of its scarcity, are changing. For example, in the northern part of Ukraine, the areas of the european snakeroot (*Aristolochia clematitis* L.), field bindweed (*Convolvulus arvensis* L.), blue lettuce (*Lactuca tatarica* L.) and others are spreading (PYSARENKO ET AL., 2019).

During recent years, the climate of the Central Forest Steppe is characterized by warming as shown by increasing average monthly temperatures of 2.0–2.6°C in summer and by 1.6–1.9°C in winter with a simultaneous moisture deficit and distribution of the precipitation throughout a year (MOSTOVYAK & DEMYANYUK, 2020). On the arable lands of the Forest Steppe, there has been observed an elevated attendance level of usual loose silky-bent (*Apera spica-venti* L.), field horsetail (*Eguisetum arvense* L.), and corn spurrey (*Spergula arvensis* L.) (IVASHCHENKO ET AL., 2017). These types of weeds are acidophytes**,** i.e. plants, which are indicators of acidic soils, poor in calcium compounds, in agrocoenoses. The lack of calcification in acidic soils in combination with acidic precipitation contributes to the gradual leaching of calcium compounds from the soil layer and acidification of arable lands. Therefore, environmental risks arise due to the loss of soil fertility in agrocoenoses and the formation of favourable conditions for the expansion of a range of acidophilic weed species.

So, in the context of climate change, there is a tendency for the actual displacement of the boundaries of natural climatic zones in Ukraine by 100–150 km to the north of the country. Simultaneously, there is a movement of flora species and its associated active invasive species, which can cause the emergence of ecological risks from the spread of adventive and invasive weed species.

3.4. Ecological risks from the loss of competitiveness of agrophytocoenosis cultures relative to the segetal phytobiota

In the process of evolution, the segetal phytobiota of agrocoenoses acquired a number of biological properties such as: high plasticity of development and fertility, a long period of seed viability through due and vegetative primordia preservation in the soil (MILENKO ET AL., 2020).

During climatic changes, the segetal phytobiota remains one of the main factors restraining an increase in the productivity of agrophytocoenoses, because it is marked by the intensity of the vegetation and enters into competitive relationships with crops for use ecological resources. Through their easy adaptability to new soil and climatic conditions, some weeds, in particular, creeping mustard (*Acroptilon repens* L.), are able to intensively increase their area of distribution. Thus, the high degree of harmfulness of creeping mustard (*Acroptilon repens* L.) is manifested by the drying and depletion of the soil because it absorbs 2–5 times more nutrients and moisture from soil than any other plant. Vegetative organs of this mustard contain toxic substances of up to 4% (glycoalkaloids), which can be poisonous tocattle (and horses), while flour containing mustard seeds becomes unfit for consumption (IVASHCHENKO ET AL., 2013).

When there is not enough soil moisture, a number of physiological processes and biochemical reactions in the soil cover are inhibited. This is definitely reflected in the adaptive barrier of most vulnerable species (SMIRNOVA ET AL., 2019). Sudden changes in weather conditions with long periods without rain with the presence of weeds lead to drying out of the arable and subsoil soil layers of agrocoenoses. Drying of the soil is caused by the powerful development of the root system, the speed of its development and the deep penetration of the roots into the soil. So, for example, the roots of common wild oat (*Avena fatua* L.) go down to a depth of more than 2 m, Canada thistle (*Cirsium arvense* L. Scop.) in the first year of life to 3.5 m (PYSARENKO ET AL., 2019).

Hydrothermal conditions affect the competitive activity of weeds with crops of agrophytocoenoses, namely, their physiological and biochemical features: the speed of onset and passage of ontogenesis periods, photosynthetic carbon metabolism during photo-synthesis (C3 and C4), allopathic interaction. Plants with C4 photosynthesis bind carbon with formation of the first product in the form of four-carbon oxalic acid, while most plants with normal C3 photosynthesis

synthesize three-carbon 3-phosphoglyceric acid. It should be noted that most crops of agroecosystems carry out the photosynthetic metabolism of carbon dioxide according to the C3 cycle, and the majority of segetal phytobiota have a C4 cycle. Plants with the C3-photosynthesis pathway have a long daylight and the optimum of photosynthesis is in the range of 19–25°C, and the minimum is at a temperature close to 0°C. Plants with the C4-photosynthesis pathway respond well to short daylight hours and, with sufficient moisture, can withstand high air temperatures (IVASHCHENKO & IVASHCHENKO, 2019).

Thus, in plants with a C4 photosynthetic cycle, competitive activity increases during long droughts compared to plants with a C3 cycle. Climatic changes may increase the spread of invasive weeds with the C4 cycle in the northern direction and weaken the biotic resistance of native plants. Recurrence of hot days can stimulate pure photosynthesis in C3 plants and increase the concentration gradient of carbon dioxide, which comes from the air to the leaves. It also reduces its loss due to photosynthesis (ANWAR ET AL., 2021). These plants include 95% of all known species, and climate changes are associated with high temperatures and CO_2 content, are favourable for their development and growth. Plants with a C4 photosynthetic pathway make up 4% of known species and are characterized by a closed internal CO_2 accumulation mechanism. An external increase in CO_2 concentration in the air has little effect on the purity of photosynthesis in them (MALARKODI ET AL., 2017).

So, under the influence of adverse abiotic factors on the phytobiota, the environmental risks of losing the competitiveness of crops relative to the segetal phytobiota can occur. These risks should be taken into account to control the phytosanitary state of agrocoenoses.

3.5. Ecological risks of increasing the number of species and distribution areas of segetal phytobiota

The primary factors influencing the spread and acclimatization of phytobiota are abiotic agroclimatic factors, which are among the key factors affecting its species composition, abundance, and naturalization of adventive species in the ecotopes of agrocoenoses due to the physiological limits of each species (SKENDŽIĆ ET AL., 2021). In the agrocoenoses of grain crops of the Ukrainian Central Forest Steppe, the number of weeds varies in the range of 19–25 species, while on row crops (maize, sunflower, sugar beet) species diversity is several times higher (SHAVRINA, 2018).

Under different soil and climatic conditions of Ukraine, weed seed contamination in the arable soil layer (0–30 cm) is: in the zone of sufficient moisture – 1.47 billion units/ha, in the zone of excessive moisture – 1.71 billion units/ha, in the zone of insufficient moisture – 1.14 billion units/ha. Increases in temperature, periodicity and intensity of precipitation accelerate the emergence of weed seeds from their dormancy and affect their distribution in space and time in agrocoenoses. An excessive amount of precipitation and a decrease in the area of the leaf surface during the ripening phase of crops contribute to an increase in weediness with annual and perennial weeds.

In the zone of insufficient moisture (Eastern Forest-Steppe), after the appearance of full seedlings of sunflower (predecessor wheat) there were 118 weeds/m^2, with dicotyledonous dominant species of: common ragweed (*Amaranthus retroflexus* L.) and ragweed (*Ambrosia artemisiifolia* L.) and in smaller quantities: white quinoa (*Chenopodium album* L.), wild mustard (*Sinapis arvensis* L.), green smartweed (*Polygonum scabrum* Moench), black bindweed (*Polygonum convolvulus* L.), black nightshade (*Solanum nigrum* L.), field pennycress (*Thlaspi arvense* L.). Among monocotyledonous weed species, chicken millet (*Echinochloa crus-galli* L.) and yellow bristle grass (*Setaria pumila* L.) (REMENYUK, 2017).

Therefore, to prevent the emergence of ecological risks due to the increase in a number of species and distribution areas of segetal phytobiota, phytobiotic monitoring should be carried out in a timely manner to assess the degree of ecological threat and the phytosanitary state of the agrocoenosis.

3.6. Ecological risks of the impact of agro-climatic conditions on the change of cultivated areas, the productivity of agrocoenoses and the quality of the harvest of agricultural crops

Because of the growing aridity of the climate and the shift of agro-climatic zones, the zonal set of agricultural crops and the area under them are changing, because each crop has its basic temperature requirements at the end of a certain phenophase and the entire life cycle (SKENDŽIĆ ET AL., 2021).

According to the data of the State Statistics Service of Ukraine (VERNER, 2021), we analyzed the dynamics of Ukrainian cultivated areas over the past 20 years under the main agricultural crops. It should be highlighted that in 2020, the ploughing of land increased by 3.58% compared to 2000, and the sown areas amounted to

28,147 thousand hectares, and 27,173 thousand hectares of sown areas were sown with the main agricultural crops. So, in 2020, the areas sown under winter wheat (*Triticum aestivum* L.) and rapeseed (*Brassica napus* L. *var oleifera biennis*) increased by 1,113 thousand hectares (3.28%) and 913 thousand hectares (3.22%) compared to 2000 (Fig. 2).

From Fig. 2, it can be seen that in 20 years, the area under sugar beet *(Beta vulgaris saccharifera*) (by 636 thousand ha), buckwheat (*Fagopyrum esculentum* Moench.) (419 thousand ha), vegetables and melon crops (by 423 thousand ha) and fodder crops (by 5386 thousand ha) decreased significantly. On the other hand, it should be noted that the area sown under sunflower (*Helianthus annuus* L.) (by 3,514 thousand ha), soy (*Glycine max* Moench.) (by 1,286 thousand ha) and corn for grain (*Zea mays*) (by 4,068 thousand ha) has increased.

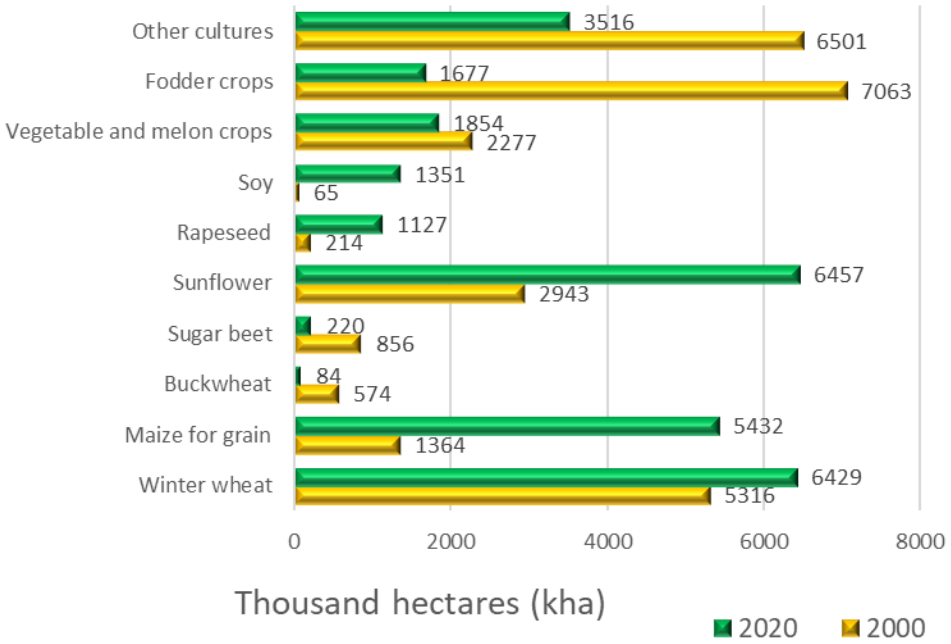


Fig. 2. Comparison of the dynamics of Ukrainian cultivated areas under the main agricultural crops in 2020 relative to 2000, (thousand hectares) (Source: constructed by the authors based on data from the State Statistics Service of Ukraine, Verner, 2021)

The productivity of food agrocoenoses depends on the presence of segetal or field weeds, pests, and pathogens. An agrophytocoenosis is formed by segetal and cultivated plants. The weeds' survival in agrophytocoenoses in different conditions of existence is determined by their competitiveness and adaptability. It is ensured by the productivity of the formation of a large number of seeds, which are able to be in a state of organic rest and maintain viability for many years. Weeds cause the greatest total potential crop yield losses, followed by pests and plant diseases. Beside this, the average loss of grain yield in the current state of weediness of crops varies in the range of 8–15% for grain crops and up to 25–40% for corn, provided that the complex of agrotechnical and chemical measures to destroy weeds is minimized (RYBKA ET AL., 2017). In particular, the minimum relative air humidity during the sunflower flowering period (r = 0.855) affects the formation of the crop, so researchers recommend taking this into account when determining sowing dates, choosing sunflower varieties and hybrids, and using anti-stress drugs (YEREMENKO & KALYTKA, 2017).

More than 90% of the agricultural crops in Ukrainian agrocoenoses are covered by weeds (SIDLYARENKO & KALASHNIKOVA, 2022). So, for example, research results show that medium and high levels of weediness (15 units/m^2 and above) lead to a decrease in chickpea productivity by 20 percent or more (SHKATULA & VOTIK, 2020). Annual average cultivation losses are: 15–20% crops; 25–30% – legumes, sunflowers, and consecutive (maize, sorghum, soy); 35–40% – vegetables and perennial herbs (KRYVENKO, 2017).

It was noted that crops of leguminous crops, in particular, chickpeas (*Cicer arietinum*), have low competitiveness against weeds in the first half of the growing season, which can contribute to a decrease in productivity. Studies have proven that the reduction

in the productivity of chickpea agrocoenoses depends entirely on the level of the weeding of its crops: in the presence of 10 weed plants/m^2, crop yield losses were 9.9%; when weed density increased to 25 plants/m^2, losses increased by 23.7%; at a density of 50 plants/m^2 - they increased to 38.2%. At the same time, at a weed density of 93.5 plants/m^2, in variants with natural weediness, the yield loss was 58.7% compared to the control (Shkatula & Votik, 2020).

Moisture conditions affect crop yield depending on its growing season. In particular, under the conditions of insufficient and unstable moisture that existed in the conditions of the Left Bank Forest Steppe during the growing season of sunflower (*Helianthus* L.) hybrids, the highest average seed yield was noted in the medium-ripening group (3.44 t/ha) (Kokhan et al., 2020).

In experiments with sunflower crops, it has been found that the qualitative indicators of the crop seed yield depended on the duration of its competition with weeds (Babenko, 2017). The author noted that the simultaneous growth of sunflower (*Helianthus* L.) with weeds from the beginning of the growing season for 20 and 60 days leads to a decrease in productivity by 11% (0.5 t/ha) and 41% (1.8 t/ha) with a simultaneous decrease in oil content, respectively by 0.9% and 6.25%, or oil collection from one hectare – by 0.25 and 1.03 t/ha, respectively. It was found that for crops with densely covered places (winter wheat, spring barley, peas) cultural plant failures depend a little bit on the number of weeds, while in row crops there is an average correlation dependence.

Therefore, in order to prevent ecological risks from crop yield losses under the influence of modern climate changes in Ukraine, which are moving towards warming and aridity, preference should be given to zoned varieties of crops. The sown areas should be adapted to crops that are characterized by high drought resistance and export capacity.

3.7. Ecological risks of the acquisition of tolerance of the segetal phytobiota of agrocoenoses to the action of herbicides and the deterioration of the effectiveness of their use under the influence of climatic changes

Climatic conditions have a direct effect on the ability of the segetal phytobiota of agrocoenoses to absorb chemical compounds of herbicides from the natural environment. This ensures the effectiveness of toxic chemicals on weeds by disrupting physiological processes and the gradual dying off of vegetative segetals. Certain biotypes of certain weed species acquire resistance that allows them to survive herbicide treatment. At the same time, the complete death of plants of this species is recorded when using herbicides under favourable conditions.

Under the influence of various environmental factors under the conditions of global warming, the number of new resistant weed biotypes is increasing every year. Thus, in the international data bank (International Survey of Herbicide-Resistant Weed) in the world (as of 2023), 515 resistant biotypes are registered, which arose from 267 plant species, of which: 154 are dicots and 113 are monocots (Heat, 2024). The reason for this is the ecological plasticity of plants, which is manifested by accelerated metabolism due to an increase in hydrothermal temperature indicators. Risks of epigenetic resistance to herbicides may arise in the segetal phytobiota of agrocoenoses adapted to stress (drought). Epigenetic changes involve modifications to gene expression that do not alter the underlying DNA sequence (Akhter et al., 2021). Epigenetic changes arise under the influence of abiotic stresses. To overcome these abiotic stresses, plants implement specific adaptations regulated by a complex biological system. Gene expression alterations occur through changes in DNA, histones (protein complexes), and the biogenesis of non-coding RNAs, as well as modifications in the nucleotide sequence. DNA methylation serves as a primary mechanism of epigenetic variation that can induce phenotypic changes in plants during periods of stress (Guarinoet et al., 2022). Resistance to herbicides through epigenetic mechanisms implies that the plants are developing heritable changes in gene expression that make them less susceptible to the effects of herbicides (Sen et al., 2022). Several studies with herbicides have shown differential expression of DNA methyltransferases, histone methyltransferases, and DNA demethylases in response to herbicides (Markus et al., 2018). The article shows that drought stress causes resistance to herbicides in the grass weed (*Alopecurus myosuroides* L.). This resistance was transmitted in the form of epigenetic resistance to it in subsequent generations of plants (Mohammad et al., 2022). Also, the increased temperature causes the metabolic detoxification of the herbicide pinoxaden in the form of a decrease in the sensitivity to it of several populations of cereal weeds (Matzrafi et al., 2016).

In general, there are over 30,000 species of plants that can be considered weeds (Zimdahl, 2018). According to the data of a selective assessment of crop weediness (Shavrina, 2018), the weediness of crops has increased from 60 to 85% in recent decades.

This is explained by the fact that the lack, or prolonged absence of, precipitation and the uneven distribution of moisture throughout the year affect the physiology of plants in the form of: an increase in the amount of wax, a thickening of the cuticle, a decrease in the opening of stomata, and a slowdown in growth. The occurrence of such changes develops an additional barrier for the penetration of herbicide molecules into the leaves of the segetal phytobiota. Drought can slow down the growth of weeds, which can lead to a decrease in the effectiveness of post-emergence systemic herbicides. Their effectiveness depends on active plant growth, translocation and the development of phytotoxic action (ANWAR ET AL., 2021). At the same time, with a lack of moisture in the soil, pre-emergence herbicides may be absorbed less by plant roots (IVASHCHENKO & IVASHCHENKO, 2019) and to lose phytotoxicity under the influence of drought stress, which was found when glyphosate treated plants of *Abutilon theophrasti* Medik (ZHOU ET AL., 2007). Without moisture and an increased acidity of the soil, a negative case of the after-effects of the herbicide Euro-Lightning (combination of active substances imazapyr and imazamox (drugs)) was found. It also has an impact on reducing the productivity of: sugar beet, buckwheat and sunflower in the form of a decrease in yield – by 29.3%, 27.6 and 26.0%, respectively (BORZYKH ET AL., 2022).

Low relative soil moisture may reduce uptake and translocation of the post-emergence nonselective herbicide Glufosinate in the tissues of several species of *Amaranthus* spp., which is inconsistent with higher levels of weed control. It is a fact that the structure of crop rotation is often dominated by grain or leguminous crops, and herbicides with the same mechanism of action are usually used in these areas. These herbicides are inhibitors of acetolactate synthase (ALS) in chloroplasts, which leads to the formation in many countries of populations of various segetal plant species that show resistance to this mechanism of toxic action (IVASHCHENKO & IVASHCHENKO, 2019). So, after applying the pre-shoots herbicide in a period of twelve days, it was noticed that cumulative precipitation exceeding the average monthly amount of moisture by at least 60% reduced the level of control of: white quinoa (*Chenopodium album* (L.) – when using metribuzin, as an inhibitor of electron transport in photosystem II, and the green foxtail (*Setaria viridis* (L.) Beauv.) – when applying imazetapir (STEWART ET AL., 2010).

According to other researchers, in C3 weed plants under the influence of repeated days with maximum temperatures, the number of stomata and respiratory conductivity of tissues may decrease and the thickness of leaves may increase, which negatively affects the absorption of herbicides, in particular glyphosate (IVASHCHENKO & IVASHCHENKO, 2019). In conditions of increased CO_2 content by 350 μM/mol compared to its amount in the environment, the researchers found: an increase in the growth rate and a disruption in the ratio of shoot mass to root mass of Canada thistle (*Cirsium arvense* L. Scop.) and a decrease in the effectiveness of the herbicide glyphosate. It was established that the decrease in the effectiveness of glyphosate is not caused by the difference in absorption by tissues, but by a decrease in the concentration of the herbicide under the influence of increased CO_2 content, which contributes to a stronger stimulation of the growth of weed roots compared to shoots (ZISKA & CONNELL, 2016). It should be noted that the decrease in herbicide effectiveness inhibits the synthesis of amino acids may occur due to a condition characterized by a decrease in protein content and an increase of the concentration of starch in weed leaves. In some studies on cheatgrass (*Bromus tectorum* L.), mouse barley (*Hordeum murinum* L.) and compass lettuce (*Lactuca serriola* L.) it was found that there were no changes in the effectiveness of glyphosate, which the authors explain as a response to an increase in the level of CO_2 or temperature (JABRAN & DOGAN, 2018).

At a high temperature in the range of 20–34°C, when using the herbicide 2,4-D, an increased level of resistance to the preparation of *Amaranthus tuberculatus* was found, and, conversely, weed elimination at a temperature of 10–24°C (SHYAM ET AL., 2019). Under the influence of increasing frequency of days with high temperatures, the effectiveness and selectivity of soil and post-emergence herbicides may be lost. The effect of elevated temperatures contributes to the intensity of growth and the acceleration of the phases of plant ontogenesis, which leads to a reduction in the period of the most effective herbicide spraying, when the competition between the culture and the segetal phytocoenosis is not critical (HOWDEN ET AL., 2007).

On the other hand, as air temperature rises, the effectiveness of post-emergence herbicides may increase due to the acceleration of their absorption by plants and translocation. Conversely, their effectiveness may decrease due to the acceleration of metabolic processes in plants. Some studies (MUCHERI ET AL., 2020) proved that increased temperatures in the range of 20–30°C reduce the effectiveness of ammonium

gluphosinate on ryegrass *(Lolium multiflorum*) and baygrass (*Paspalum notatum*), and at temperatures of 10–20°C the percentage of weed destruction was significantly higher. For the ALS herbicide MON 37500, which is an inhibitor of the enzyme acetolactate synthase (ALS), it has been proven that low air temperature weakens its metabolism in the studied species of segetal phytobiota: cylindrical condyle (*Aegilops cylindrica* Host.), wild oats (*Avena fatua* L.), cheatgrass (*Bromus tectorum* L.), however, soil moisture does not affect this indicator (Olson et al., 2011).

So, under the influence of drought, high temperatures, high CO_2 content, ecological risks of acquiring tolerance of segetal phytobiota and deterioration of the effectiveness of herbicides in agrocoenoses may occur, which requires their early assessment, where the earliest diagnosis in field conditions is important.

4. Conclusion

The possible ecological risks have been defined due to the influence of the actual, or potential threats, to the deterioration of the phytosanitary conditions of agrocoenoses caused by increased weeding in the change in abiotic factors, such as air temperature, precipitation, and an increase in the concentration of carbon dioxide.

The changes of air temperature and soil moisture in the conditions of climate change are the main predictors that cause the exacerbation of environmental risks associated with the phytosanitary state of agrocoenoses, namely: spread of adventive and invasive plant species; loss of competitiveness of agrophytocoenosis crops relative to segetal phytobiota; increase in the number of species and distribution areas of the segetal phytobiota; change in the sown area, productivity and quality of the harvest of agricultural crops of agrocoenoses; acquisition of tolerance of segetal phytobiota of agrocoenoses and deterioration of the effectiveness of herbicide application under the influence of climatic changes.

We have highlighted the possible consequences of the occurrence of environmental risks. We have proved that the problems of the spread of weeds and invasive alien plants in agro-ecosystems due to changes in their range and increase in population density are caused by the fluctuations in agro-climatic indicators. All of the above-mentioned environmental risks associated with the aggravation of the phytosanitary condition of crops inevitably lead to a loss of productivity of agrocoenoses and a decrease in the quality of the obtained plant and agricultural products.

Also, with the productivity loss of the weedy agrocoenosis, there are environmental risks, which are caused by the increased need for using plant protection products to ensure the control of the phytosanitary state of the agrocoenosis. The guarantor of reducing environmental risks and increasing the ecological safety of agrocoenoses is the timely implementation of appropriate agrotechnical, protective and preventive measures, which increase the adaptive capacity of agrocoenoses.

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