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Evaluation of the Effect of Herbicides and Growth and Development Regulators on the Biological and Economic Properties of Plants in Various Landscapes

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Abstract

The research aimed to study the protective effect of the Epin-Extra and Zircon preparations when used with the Stomp and Dianat herbicides in plant cultivation. In all studies, barley served as a test culture. Barley is an excellent model bioobject for genetic and environmental studies. We studied the effect of these preparations on the initial stages of ontogenesis, growth, development, and productivity of barley. In order to determine the mutagenicity of herbicides, we used laboratory germination, growth dynamics, phytotoxicity, formation of chlorophyll mutations, cytotoxicity, and productivity of barley as tests. The following methods were used: (1) seed germination with the use of filter paper rolls and polyethylene, (2) cytogenetic analysis, and (3) field experiment. All studies were performed according to a single scheme. The experimental results were statistically processed. Studying the germination rate and laboratory germination of barley showed a positive effect of the Epin-Extra and Zircon growth regulators when combined with herbicides. Under the action of herbicides on 10-day-old barley seedlings, we observed a strong toxic effect, which was significantly reduced when herbicides acted jointly with growth regulators. The chlorophyll mutations found in the study of plant growth dynamics indicated a mutational process occurring under the action of the Dianat. The mutagenicity of the studied herbicides was revealed by the cytogenetic method. The drop in mitotic activity and an increase in the frequency of chromosome aberrations in meristematic cells of barley indicated this. The effect of the Epin-Extra and Zircon growth regulators improved the process of cell division and significantly reduced the frequency of chromosome aberrations; that is, at the cellular level, they were most effective. The protective effect of growth regulators, when used together with herbicides, was also manifested in a field experiment: Already when production doses of herbicides are reduced by half, the yield significantly increases, the effectiveness of bioprotection is maintained, and the use of plant growth regulators strengthens and enhances the result. Changing the recommended doses makes it possible to significantly reduce the pesticide pressure on agrocenoses, which can considerably improve the state of the environment. That is, practical tasks are also solved to obtain hygienically high-quality agricultural products and to ensure rational and environmentally safe farming. Based on our scientific and experimental material, it seems possible to promote the minimization and control of the applied chemicals in modern plant growing, taking into account the ecological and biological characteristics of the grown plants, the properties of ecosystems, the ecological-geographical and functional-economic characteristics of landscapes.

Keywords: *Biotests, Seed Quality, Herbicides, Plant Growth Regulators, Dianat, Epin-Extra, Zircon, Phenological Monitoring, Mutation Process, Chromosomal Aberrations, Mitotic Activity, Phytotoxicity, Cytotoxicity, Level of Protection, State of Crops and Phytocenoses, Productivity, Ecological and Hygienic Safety.*

Introduction

At present, the importance of overcoming the socio-economic problems facing Armenia often leads to neglect of environmental issues. Current environmental conditions in agricultural production are characterized by a high level of anthropogenic pressure on agrocenoses, a significant contribution to

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pollution of which is made by pesticides. Most of the pesticides used are herbicides and desiccants (Zakharenko, 1990, Zhan et al., 2018; Mikhaylikova et al., 2020); at the same time, the volume of organic and mineral fertilizers has sharply decreased in recent years (Harutyunyan, Mikaelyan, 2021), leading to a deterioration in soil fertility and a drop in crop yields. The increasing amount of decrease

in the viability of cultivated crops, and a violation of the genetic uniformity of cultivated plant varieties (Damalas & Eleftherohorinos, 2011; Tudi et al., 2021). Pesticides, if used inappropriately, can cause toxic pollution of the environment (Bayili et al., 2024), suppression of resistance and reduction of crop yields, suppression of soil microbiota activity and other adverse effects on ecosystems and on the health of consumers of agricultural products from a given area (Huang et al., 2005). The environmental hazard also lies in the context of the loss of genetic diversity of cultivated plants (and native plants in neighboring – ecotone – natural ecosystems) and in their unwanted genetic modifications (Cronan, 2023). There is a legitimate concern about the negative impact of pesticides on "non-target" organisms, for example, on pollinating insects (Vommaro & Giglio, 2024).

These factors raise concerns about food safety and the negative impact of agricultural production on the environment (De Bortoli et al., 2009, Parker et al., 2023; Mansfield et al., 2024; Zhang et al., 2024). Searching for and studying substances that can reduce the level of mutations in agrocenoses when pesticides are used have become increasingly urgent (Galstyan et al., 2024; Karimi-Maleh et al., 2024; Shahid et al., 2024).

These substances include plant growth regulators that mobilize metabolic processes in plants, increase the resistance of crops to biotic and abiotic stresses, increase yields, and reduce the pesticide load on plants (Nickell, 1984; Rademacher, 2015, 2020; Rostami & Azhdarpoor, 2019; Bhatla & Lal, 2023). The use of phytohormones as a means of protection against pesticide stress has been widely used (Prusakova et al., 2005; Osipova & Avakian, 2006; Shapoval, 2014; Varshney et al., 2015; Sharma et al., 2024).

Materials and Methods

The research aims to study the protective effect of the Epin-Extra and Zircon plant growth regulators when used with the Stomp and Dianat herbicides in cultivating winter barley. According to the stated goal, the research tasks are as follows:

- To identify the negative effect of herbicides on the initial stages of barley ontogenesis;
- To determine the cytotoxicity and mutagenic activity of herbicides;
- To study the effect of herbicides on the growth, development, and productivity of barley;
- To study the antimutagenic and protective effect of the Epin-Extra and Zircon plant growth regulators when jointly used with herbicides.

The series of laboratory experiments, cytogenetic studies, and a field experiment were conducted as part of the research. In all studies, winter barley of the Mush variety of local selection, obtained by hybridization, served as a test culture. The Mush variety (var. pallidum) has the good, genetically determined productivity and serves as the control for comparison with other barley varieties. Stomp and Dianat herbicides (active constituents – 330 g/l pendimethalin and 480 g/l dimethylamine salt, respectively) were used as mutagenic factors. Taking into account the recommended doses (Terlemezyan, 2013), we selected herbicide concentrations of 0.4% and 0.2% for Stomp and 0.1% and 0.05% for the Dianat, while the production dose was 0.4% for the Stomp and 0.1% for the Dianat.

The Epin-Extra and Zircon were used as means of protection against the negative effects of herbicides. Many works (Malevannaya, 2004; 2007; Vakulenko, 2017) present the description and mechanisms of action of these preparations in detail; here, we only note that we used the Epin-Extra and Zircon (active constituents – phytohormone 24-epibrassinolide and the mixture of hydroxycinnamic acids, respectively) according to the recommendations of the manufacturer (Nest M) for seed treatment.

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The effect of the Stomp and Dianat and their combined effect with the Epin-Extra and Zircon preparations on the initial stages of ontogenesis, growth, development, and productivity of barley were studied. Germination, growth dynamics, phytotoxicity, formation of chlorophyll mutations, cytotoxicity, and productivity of barley served as tests for herbicide mutagenicity. The growth dynamics was determined by the method of seed germination with the use of filter paper rolls and polyethylene. The germination rate and seed germination were determined on Day 3 and Day 7, respectively; the length of the roots and seedlings was determined on Day 10 to identify the total toxic effect. Experiments were conducted in four repetitions.

Cytogenetic studies allow determining the effect of the used preparations on the process of proliferation in the root meristem of barley seedlings and the pathology of mitoses in the ana-telophase of the mitotic cycle. Cytogenetic (anaphase) analysis was performed according to the generally accepted method (Pausheva, 1988).

The effect of the test substances on the yield of barley was studied by the method of micro field experiment (with the sequential placement of variants, four repetitions, the area of the experimental plot of 1 m^2, the accounting area of 0.5 m^2, and no background fertilizer, an ordinary sowing scheme, the distance of 15 cm between rows, the distance of 10 cm between plants in the row). Sowing was done in October, and harvesting – in June.

All studies were performed according to a single scheme. Barley seeds were treated for 4 hours with the Epin-Extra and Zircon solutions and for 2 hours with herbicides according to the variants. When the action was joint, the seeds were treated with a growth regulator and then with the herbicide. In the field experiment, seeds were treated with growth regulators before sowing, and herbicides were sprayed in the field. In the case of the Stomp, the soil was treated immediately after sowing, and the Dianat was sprayed in the spring at the end of the tillering phase.

The obtained data were statistically processed using the MS Excel and Statistics. For laboratory studies, the average values of the indicators and their standard deviations were calculated. The data of the field experiment were subjected to analysis of variance with the calculation of the smallest significant difference (a=0.05). The Student's t-test was used to determine the validity of the results. The results are presented in tables and figures.

Results

Several methods were used to comprehensively assess the effect of herbicides and growth regulators on barley. The effect of these preparations on the sowing qualities of seeds was studied. The seeds of the previous reproduction of barley from field experiments were used in the experiment. Laboratory germination of seeds (Fig. 1.) was determined according to the GOST 12038-84 (Interstate standard).

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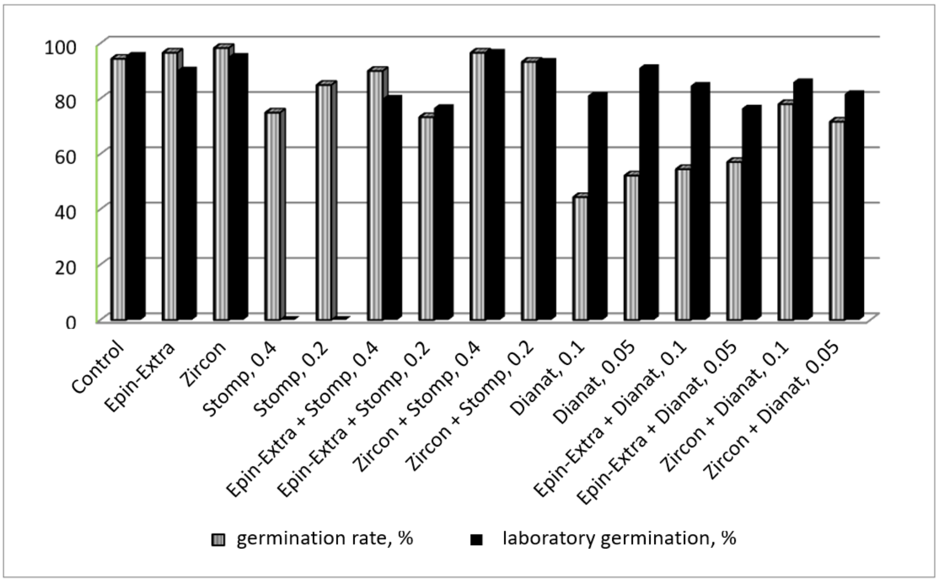

Figure 1. Effect of the Herbicides and Growth Regulators on the Germination Rate And Laboratory Germination Of Barley.

Source: Compiled by the authors.

The indicators of the germination rate and laboratory germination were the highest in the control, "that is, the ability of embryos and seeds to quickly activate enzyme systems and cell division remained high" (Gunar, 2009). Under the action of the Epin-Extra and Zircon growth regulators, the germination rate slightly increased, and germination was at the control level. Under the action of the Stomp, the seed germination rate decreased by 9–19% compared to the control, and there was no laboratory germination. Under the combined action of the Stomp and Epin-Extra, laboratory germination was restored, yielding to the control by 15–19%. Under the combined action with the Zircon, laboratory germination and the germination rate were at the control level. Under the action of the Dianat, the germination rate was suppressed greater than germination

Table 1 presents the effect of different concentrations of the Stomp and Dianat herbicides together with the Epin-Extra and Zircon growth regulators on the dynamics of barley growth.

Table 1. Total Toxic Effect of The Herbicides On 10-Day-Old Barley Seedlings.

Variants	Average stem length, cm	Relative stem length, % to control	Total toxic effect, %	Average root length, cm	Relative root length, % to control	Total toxic effect, %
Control	21.0±1.0	100	-	18.4±0.4	100	
Epin-Extra	20.6±1.3	98.1	1.9	17.3±0.4	94	6
Zircon	21.2±1.0	100.9	-	18.0±0.5	97.8	2.2
Stomp, 0.4	-	-	100	-	-	-
Stomp, 0.2	-	-	100	2.8±0.5	15.2	84.8
Epin-Extra + Stomp, 0.4	2.7±0.2	12.8	87.2	2.3±0.6	12.5	87.5
Epin-Extra + Stomp, 0.2	3.7±0.4	17.6	82.4	2.5±0.1	13.6	86.4
Zircon + Stomp, 0.4	2.7±0.3	12.8	87.2	4.1±0.9	22.3	77.7
Zircon + Stomp, 0.2	3.4±0.3	16.2	83.8	5.2±0.9	28.3	71.7
Dianat, 0.1	7.2±0.4	34.3	65.7	10.7±0.8	58.2	41.8
Dianat, 0.05	7.7±0.7	36.6	63.4	12.3±0.7	66.8	33.2

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Epin-Extra + Dianat, 0.1	7.5±0.5	35.7	64.3	11.2±0.5	60.9	39.1
Epin-Extra + Dianat, 0.05	9.6±0.4	45.7	54.3	11.8±0.8	64.1	35.9
Zircon + Dianat, 0.1	9.1±08	43.3	56.7	13.3±0.9	72.3	27.7
Zircon + Dianat, 0.05	9.1±0.7	43.3	56.7	15.9±0.6	86.4	13.6

Source: Compiled by the authors.

The toxic Stomp effect reached 100%. Growth regulators reduced toxicity by 10–15% (stems). The Dianat toxicity was comparatively lower – up to 60%, and the protective effect of regulators was about 8–10% (stems). The greatest protective effect was observed under the action of the Zircon with small doses of the Stomp and Dianat on barley roots.

When studying the effect of herbicides and growth regulators on plant growth dynamics, we found a large number of chlorophyll mutations in 10-day-old barley seedlings (Table 2). It is known that chlorophyll mutations can serve as the indicator of the mutation process as a whole (Kalam & Orav, 1974; Kumari et al., 2024; Stuart et al, 2024).

Table 2. Chlorophyll Mutations Formed as A Result of The Action of the Herbicides

Variants	Total	Chlorophyll mutations			
		Absence /typica/	Albina	Tigrina	Viridis
Control	25	25			
Epin-Extra	25	25			
Zircon	25	25			
Dianat, 0.1	25	12	11	2	
Epin-Extra + Dianat, 0.1	25	15		4	6
Zircon + Dianat, 0.1	25	14		2	9
Dianat, 0.05	25	12	7	4	2
Epin-Extra + Dianat, 0.05	25	11		2	12
Zircon + Dianat, 0.05	25	14		1	10

Source: Compiled by the authors

The research showed that under the action of both Dianat concentrations, the Albina mutation (absence of chlorophyll) was formed; this mutation was the most dangerous since such plants were not viable. The Tigrina column contains all mutations characterized by alternating longitudinal yellow, green, and white transverse stripes. In this case, the survival of plants depended on the amount of chlorophyll. With the Viridis chlorophyll mutation, plants quickly recovered while maintaining viability. Table 2 shows that Zircon and Epin-Extra demonstrated a protective effect.

These methods do not require long-term studies and can be used to quickly assess the effect of herbicides and other drugs on test objects.

The next method for determining the mutagenicity of the studied herbicides and the protective effect of growth regulators was a cytogenetic method for identifying the mitotic activity and frequency of chromosome aberrations in barley meristematic cells. Fig. 2 shows that both Dianat concentrations significantly inhibited cell division, and when they were combined with the Epin-Extra and Zircon, the process of cell division improved.

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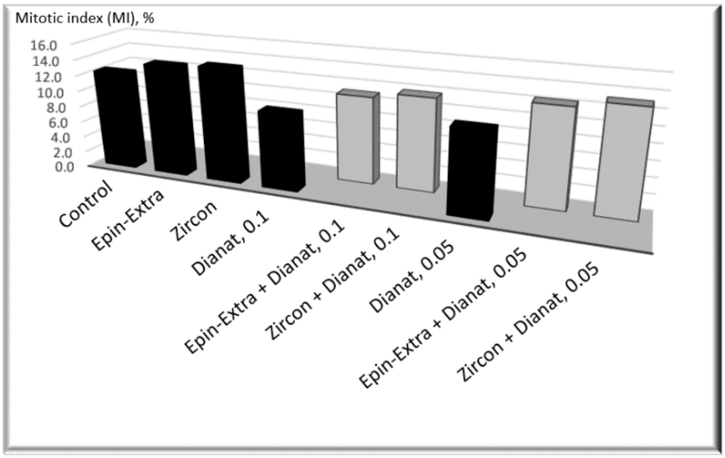

Figure 2. Mitotic Activity of Barley Meristematic Cells Under the Action of The Dianat and Epin-Extra and Zircon Growth Regulators.

***Source*:** Compiled by the authors.

Fig. 3 and Table 3 show a high mutagenic effect of both Dianat concentrations compared to the control since they produced three times more chromosome aberrations. The level of protection of both growth regulators when Dianat was used in the production concentration was almost the same and reached 30%. Reducing the production concentration by half increased the level of protection of the Epin-Extra to 40% and the Zircon to more than 50%. Thus, the effectiveness of the Epin-Extra and Zircon plant growth regulators was the highest at the cellular level.

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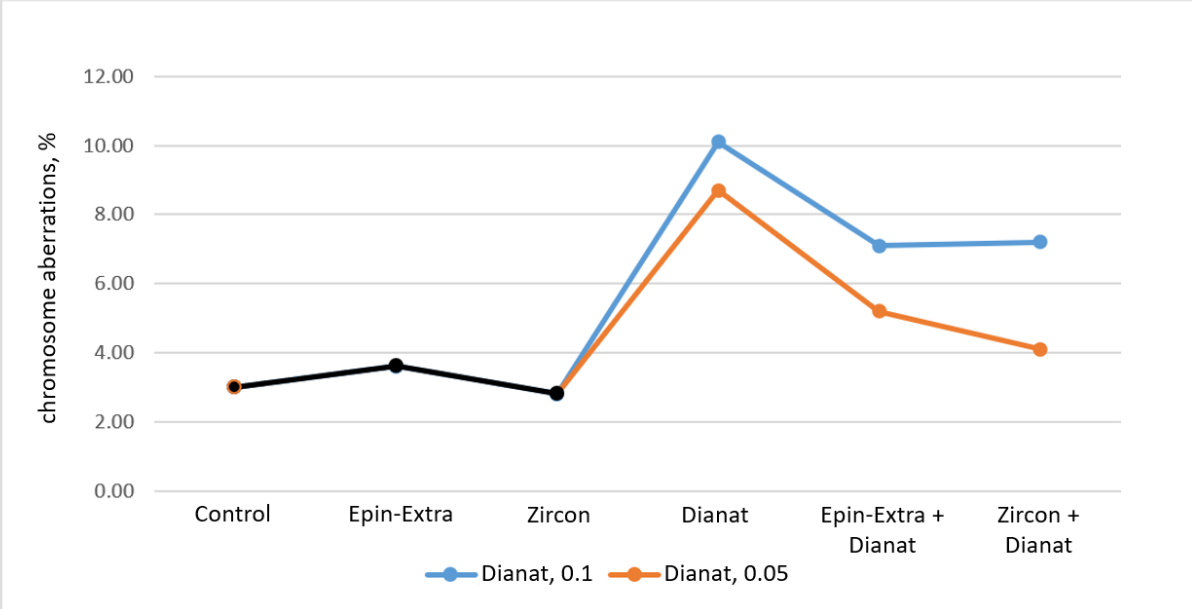

Figure 3. Frequency of Chromosome Aberrations in Barley Meristematic Cells Under the Action of The Dianat and Growth Regulators.

Source: Compiled by the authors

Table 3. Level of Protection in the Combined Action of the Dianat and Growth Regulators

Variants	Chromosome aberrations, %	Level of protection, %
Control	3.0±0.6	
Epin-Extra	3.6±0.8	
Zircon	2.8±0.8	
Dianat, 0.1	10.1±1.6***	
Epin-Extra + Dianat, 0.1	7.1±1.4**	29.7
Zircon + Dianat, 0.1	7.2±1.2**	28.7
Dianat, 0.05	8.7±1.5***	
Epin-Extra + Dianat, 0.05	5.2±1.0	40.2
Zircon + Dianat, 0.05	4.1±1.3	52.9

Note: $^{**}P_{0.99}$, $^{***}P_{0.999}$. *Source*: Compiled by the authors.

The main method for assessing the effectiveness of protective measures is the yield of the plant as a total indicator of all changes in its metabolism under specific growing conditions (Table 4).

Table 4. Formation Of Barley Yield Structure Under the Action of The Herbicides and Growth Regulators.

Variants	Plant height, cm	Tilling capacity		Ear length, cm	Number of rachises		Number of grains	Grain weight, g	Weight of 1,000 grains, g	Yield, t/ha
		Total	productive		total	sterile				
Control	89.3	5.1	4	7.2	64.7	15.9	48.8	2.4	49.2	4.48

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Epin-Extra	112.2	6.9	4.9	9.1	85.8	22.3	63.5	3.09	48.7	7.06
Zircon	109.4	7.5	5.2	8.1	72.9	19.3	53.6	2.69	50.2	6.52
Stomp, 0.4	81.4	5.9	3.2	8.2	78.3	36.3	42	1.77	42.1	2.64
Stomp, 0.2	97.7	6.8	3.9	7.7	75	25.3	49.7	2.31	46.5	4.2
Epin-Extra + Stomp, 0.4	104.4	7.3	3.6	8.3	81.3	17.8	64.5	2.98	46.2	5
Epin-Extra + Stomp, 0.2	102.9	5.6	4.6	8.1	81.9	22.7	59.2	2.92	49.3	6.26
Zircon + Stomp, 0.4	108.5	6.1	4.3	9.1	87.6	17	76	3.07	43.5	6.63
Zircon + Stomp, 0.2	105	5.7	4.2	8.7	83.4	16.9	62.5	2.97	47.5	5.81
Dianat, 0.1	81.3	4.6	3.2	9.3	87	28.3	58.7	2.53	43.1	3.77
Dianat, 0.05	88.9	8.7	4.9	8.7	79.8	19.2	60.6	2.68	44.2	6.17
Epin-Extra + Dianat, 0.1	84.1	5.4	4.2	8.9	83.3	26.5	58.8	2.8	47.6	5.48
Epin-Extra + Dianat, 0.05	84	6.2	4.7	7.1	73.8	23.4	59.7	2.83	47.4	6.2
Zircon + Dianat, 0.1	101.1	6	4.5	7.4	66	17.1	53.9	2.63	48.9	5.28
Zircon + Dianat, 0.05	109.2	7.3	4.9	8.9	85.8	25.7	60.1	2.94	48.9	6.71
Least significant difference $_{05}$	3.75			0.6			2.3			0.2

Source: Compiled by the authors.

Phenological observations were made during the growing season. In the initial stages of vegetation, chlorophyll mutations were found, and plants with the Albina and Xanta mutations were not viable; only the Tigrina and Viridis mutations were found in the tillering phase. Chlorophyll mutations appeared at the beginning of the exit into the tube in the form of narrow light stripes devoid of chlorophyll. As a result of the death of non-viable plants, the total number of plants in the field decreased. In the variants with Dianat, modifications of scales and awns were also found.

The yield of grain crops is formed due to productive tillering, the number of grains per ear, and the weight of 1000 grains. Table 4 shows that under the action of production concentrations of Stomp and Dianat, there was a sharp drop in these values and, accordingly, the yield. The yield of the production concentration was less by 41% for the Stomp and by 16% for the Dianat compared to the control. Halving the production concentrations of herbicides and using them jointly with growth regulators significantly increased yields while maintaining the effectiveness of herbicides.

Discussion

The choice of the test object for studies depends on the solution to specific tasks facing the researcher. Barley is the "classic" object for studying the mutability and toxicity of chemical products used in agricultural production. The choice of the test object made it possible to comprehensively study the action of the Stomp and Dianat herbicides together with the Epin-Extra and Zircon growth regulators at the level of the organism, at the cellular level, and at the level of phytocenosis. At all levels of the research, the Epin-Extra and Zircon showed a high protective effect; the strongest protective effect was noted at the cellular level under the action of a halved production dose of the Dianat together with growth regulators. Previously, we studied the effect of the Stomp and Dianat herbicides on wheat morphogenesis (Osipova & Voskanyan, 2017). As a result of field experiments, it was found that decrease in the consumption rate of the pesticide led to the decrease in the phytotoxic effect on wheat while maintaining the effectiveness of bioprotection.

However, some researchers point to the instability of the Epin-Extra and Zircon growth regulators in

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years with different weather conditions (Novikova & Kosikov, 2017). In our studies, even a single use of growth regulators (treatment of seeds before sowing) proved to be effective. Single spraying with a mixture of herbicides and the Zircon preparation led to an increase in photosynthetic activity and an increase in the yield of fiber and seeds of fiber flax (Gunar et al, 2017). The use of the Epin-Extra as a protector with clay herbicide did not increase the yield of potatoes, but it affected the quality of the crop, significantly increasing the starch content in tubers (Voronina et al., 2015). The use of the phytohormone 24-epibrassinolide and preparations based on it led to an increase in the yield of carrots, beets, and other vegetable crops and improved product quality (Voronina & Malevannaya, 2019). An important issue is the frequency of application of plant growth regulators to overcome herbicide stress since the excessive application of these substances can cause desensitization of the immune system of plants and imbalance of hormones to the detriment of productivity (Naumov & Zimina, 2019). The issues of the frequency of application and the choice of the development phase of a particular crop for the use of plant growth regulators have not been studied enough and require further research.

Our studies are especially important in the context of global warming (Lubimov et al., 2016; Larionov et al., 2018, 2021; Kotiyal & Gupta, 2024; Vala et al., 2024). As is known, global warming limits agricultural crop production (Kar et al., 2024; Vala et al., 2024), horticulture (Koriesh & Abo-Soud, 2020), vegetable gardening (Nag et al., 2023), floriculture, landscaping (Larionov et al., 2018, 2021, 2023) and other types of crop production (Volodkin et al., 2022; Galstyan et al., 2023). Unfortunately, in many regions, including Russia, Armenia, Georgia and other parts of the Caucasus, the Southwest, Central and South Asia, the East Asia, Africa and other territories, global climate change has caused climate aridization and desertification of natural and cultural landscapes.

In modern crop production, due to the need to switch to organic farming (Devi et al., 2024; Majhi, 2024; Pogibaev & Larionov, 2024), regulation of carbon (Larionov et al., 2023; Lee et al., 2024; Muni Kumari & Durge, 2024; Pogibaev & Larionov, 2024; Jalali et al., 2024), nitrogen (Choudhary et al., 2024; Larionov et al., 2024b; Nissanka et al., 2024), water (Pleshakova et al., 2021; Galstyan et al., 2023; Larionov et al., 2024a; Nissanka et al., 2024) and other geochemical flows and cycles (Gibadulina et al., 2024) al., 2022; Volodkin et al., 2022; Galstyan et al., 2023; Ngun et al., 2023; Choudhary et al., 2024; Kaur et al., 2024; Kotiyal & Gupta, 2024; Larionov et al., 2024a; Nissanka et al., 2024), the search for opportunities to reduce the use of chemicals has become relevant. The issue of not only the complete elimination of the use of chemicals in crop production is important (this is not always justified and possible, it is not always necessary). It is also important to justify the use of the necessary names and doses of the corresponding chemicals, taking into account the number of environmental, physical-geographical, economic and other objective conditions.

Decarbonization of crop production (Larionov et al., 2023), including in agriculture (Jalali et al., 2024; Larionov et al., 2024a; Pogibaev & Larionov, 2024) and, in particular, in semi-arid and arid regions (Larionov et al., 2024b; Muni Kumari & Durge, 2024; Jalali et al., 2024), can be carried out with effective and continuous monitoring of the growth, development and productivity of cultivated phytocenoses. This is advisable throughout the entire period of vegetation and fruiting. Managing the growth and development of plants, increasing their stability and bioproductivity are conditions for sustainable deposition of organic carbon in the biomass of phytocenoses and in soils. In fact, caring for cultivated plants with a justified reduction in the use of pesticides and other chemicals and with the use of bioecologisation techniques in agriculture allows us to achieve conditions for the environmental safety of plant production and bioprotection of soils, stabilisation and improvement of the environmental and resource characteristics of landscapes.

It is also necessary to conduct annual and long-term analysis of the dynamics of carbon cycles and cycles of other biogenic elements in cultural ecosystems and in adjacent natural ecosystems. Of course, monitoring and regulation of biogeochemical cycles of carbon and plant nutrients is necessary with the justified use of fertilizers (Rehman et al., 2024; Jalali et al., 2024), stimulants, growth regulators and chemical plant protection products. Such procedures should be carried out using environmentally sound techniques and methods, including using this work and our other works (Galstyan et al., 2023; Larionov et al., 2024b).

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Based on the productivity (one of the main qualitative features) of phytocenoses (Lebedev et al., 2023; Larionov et al., 2024b; Pogibaev & Larionov, 2024; Slavskiy et al., 2024) as an important ecofunctional and economic characteristic of the emergence of created ecosystems, one can judge the corresponding levels of biocarbon deposition in phytocenoses and soils (due to the mutual ecosystem connection in the plant – soil – ground atmosphere systems). By increasing the yield of agricultural plants, we ensure the fixation of ecologically significant carbon in the form of phytomass of ecosystems. Accordingly, by ensuring the ecological and physiological stability of grown plants, we create conditions for an ecologically favorable biogeochemical background, for bioprotection and biorestoration of soils, for bioecologized cultivation and ecological stabilization of landscapes.

Control of the chemicals used in modern plant growing in combination with bioecologisation techniques for land use (i.e. the true – nature-like – approach in organic farming) can effectively solve economic and environmental goals.

In our case, we used barley as a biotest to determine environmentally safe doses of chemicals for plants and as a universal and reliable bioindicator of bioproductivity, the state and sustainability of cultural ecosystems and, consequently, the ecological potential of soils and the resource capacity of landscapes.

The implementation of developments in organic farming, primarily in bioecologisation of farming, must be integrated with activities to reduce the volumes of chemical plant protection products, weed and undesirable vegetation inhibitors used. That is, issues of rationalisation of crop land use must be considered and implemented comprehensively, systematically and on a scientifically sound basis.

Our work shows examples of minimizing the pesticide load for agrophytocenoses and, consequently, for the health of livestock and people (the final consumers of agricultural products). In general, the idea of our work is aimed at creating ecological and biogeochemical conditions for ensuring and maintaining the ecological stability of ecosystems and landscapes, for the ecological and hygienic safety of the environment. The research materials deserve widespread implementation in practice. In addition, the results may be of practical interest to crop farms in different regions of the world: in Russia, the Caucasus, and others. The work shows a trend towards the need to modernize approaches to caring for crops, monitoring the chemicals used, creating ecological and hygienic safety of agricultural products and conditions for environmental protection of the environment.

The results, conclusions, generalizations and speculations are significant for the territories of Russia, Armenia, Georgia, Azerbaijan, the Central, Western and Eastern Asia, Oceania. Our work can also be useful for agricultural regions of Africa, the South America, the south of the North America, etc. There is an understanding of the objective danger of pesticides. It is necessary to control the use of plant growth regulators, as well as fertilizers and other means of chemicalization in modern crop production. In addition, species and varietal biological and ecological properties, as well as soil-ecological, physical-geographical and weather-climatic conditions of landscapes can also be important in matters of ensuring stable high yields, sanitary-hygienic and physical-chemical quality of the obtained agricultural raw materials and characteristics of the environmental situation.

In addition to all of the above, the completed research work is of high importance as a scientific-conceptual, methodological and reference material for in-depth meta-subject and interdisciplinary training, for educational and industrial practices of future agronomists, phytopathologists, agrochemists, biologists, ecologists, landscape scientists and specialists in related fields. All the scientific and educational issues disclosed are designed to form students' understanding of environmentally and economically efficient management of plant-growing nature management, rationalization of bioresource use and land use, regulatory requirements and experimentally substantiated methods of green management. All this solves the goals of economic, food, hygienic and environmental safety, including in areas with abnormal manifestations of global warming and anthropogenic transformation of landscapes.

Substantiated and tested advanced plant growing practices, directions and methods of

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bioecologicalization of agriculture and ecological monitoring of cultural phytocenoses and their resource-economic characteristics meet the needs in the formation of a modern ecological culture – the culture of bioecological rationalization in plant growing. Practical tools for bioecologicalization of agriculture include the ideas of ecohumanism, ecoeducation and geoecological regional studies.

Conclusion

Under the action of production and halved production doses of the Stomp and Dianat herbicides, the germination rate and seed germination of barley were suppressed, and stable phytotoxicity was manifested in terms of the length of roots and stems. In the production concentration, the Dianat formed a significant number of chlorophyll mutations, some of which were not viable, which reduced the number of plants per unit area.

The negative effect of the Dianat on the mitotic index and the formation of chromosome aberrations in meristematic cells of barley indicate the high cytotoxicity and mutagenicity of this herbicide. Field studies showed the negative effect of the Stomp and Dianat herbicides on barley yields. The Epin-Extra and Zircon preparations significantly improved all the studied parameters. The germination rate and seed germination of barley improved, the number of plants with chlorophyll mutations and the number of chromosome aberrations were significantly reduced, and yield indicators increased.

The effectiveness of these preparations depended on the dose of the herbicide and the individual sensitivity of the culture under study. In this regard, it is important (1) to reduce the doses of herbicides recommended by manufacturers when used together with growth regulators and (2) to identify the optimal amounts of herbicides and plant growth regulators used for each crop. Reducing the consumption of pesticides can significantly improve the state of agrocenoses and the whole environment.

Scientific substantiation and strict control of the use of pesticides and other chemicals in agriculture, as well as in gardening, horticulture, forestry, landscaping and park management, floriculture and nursery are required. It is necessary to ensure permanent biogeochemical monitoring of cultivated phytocenoses and soils for the accumulation and migration of pesticides, heavy metals and other toxic substances.

It is useful to develop and implement programs for monitoring and control of geochemical cycles in soil-plant systems in cultural landscapes and in adjacent cultural and natural ecosystems (for example, in natural ecotone forest or aquatic ecosystems, in adjacent soil-protective forest plantations, in agroforests and landscape protection greening complexes). The same applies to control of migration routes and cycles of undesirable substances from the composition of agricultural chemicals (and also from landscaping and forestry, phytomeliorative and agroforestry plant growing).

Ecological and toxic control of pollutants must be carried out simultaneously (in parallel) with the control and correction of migration cycles of carbon, nitrogen, phosphorus and other biogenic elements, microelements and macroelements as objects of nutrition and means of maintaining life activity for plants. All this will be the fundamental and informational function of ecological management of cultural phytocenoses and soils.

It is advisable to switch to organic (biological) farming on lands of different target categories and taking into account local weather and climate factors in their variability (including taking into account global warming and its aridization in sub-humid, semi-arid and arid territories). This will allow us to gradually abandon the excessive use of fertilizers, pesticides and other chemicals that saturate the grown plants and worsen their physical, chemical and hygienic properties. That is, it is important to comply with the requirements for hygienic safety in relation to the resulting agricultural food products and the environmental safety of the environment.

In all cases, as the research material has shown, it is useful to use barley in environmental monitoring of the state and resource properties of cultural landscapes. On the one hand, it is a valuable agricultural crop. On the other hand, this plant shows high reliability as a biotest system for the state of agroecosystems, the need (according to the criteria of hygienic hazard of products) and the effectiveness of the means used. The yield and other biological and economic qualities of barley must be taken into account in agrochemical and environmental monitoring, as well as in programs for organic land use, adaptive landscape farming, agricultural technology of cultivation, phytomelioration and agroforestry amelioration of landscapes, bioprotection of soils using various phytoecological techniques.

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