AGROLOGY

ISSN 2617-6106 (print)
ISSN 2617-6114 (online)
Agrology, 2022, 5(2), 43–48
doi: 10.32819/021106

Original researches

Received: 07.04.2022
Revised: 01.05.2022
Accepted: 04.05.2022

Early depressive effects of epimutagen in the first generation of winter wheat varieties

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Cite this article: Beiko, V., & Nazarenko, M. (2022). Early depressive effects of epimutagen in the first generation of winter wheat varieties. Agrology, 5(2), 43–48. doi: 10.32819/021106

Abstract. The research has been conducted on the possible depression impact of epimutagen Triton-X-305 in concentrations of 0.01%, 0.05%, 0.1% and 0.5% in the first generation of winter wheat varieties after one time action. The study was performed on the local Podolyanka, Spivanka and foreign varieties Altigo, Courtot, Lyrik, and Flamenko. The varieties were selected in order to maximize the possible biodiversity of winter wheat and to compare the features of mutagen depression, depending on the overall adaptive ability to these natural and climatic conditions and the individual reaction of genotype variety to the nature of the compound, expressed in the genotype-mutagen interaction. The purpose of the research was to identify possible depressive effects of the epimutagen Triton X-305 and to show key points for obtaining the necessary amount of research material for further scrutiny and identification of forms with possible valuable changes. We analyzed the indices of germination, survival and related physiological parameters of activity during critical periods of wintering (phenological assessment and measurement of sugar concentration in the node during different adverse periods) and earing (photosynthetic activity) which may be indicative of both genotype-mutagenic interaction and depression effect in general. We determined that most of these indices revealed both the specific reaction of individual varieties to the action of the agent and were changed depending on its concentration. It is shown that reliable parameters of variability under the action of the preparation were germination, survival after winter, concentration of sugars during the growing period and overcoming the most adverse conditions of winter time, photosynthetic activity during the period of the earing. We determined that the latter trait is more variable in varieties of domestic selection, which indicates their more heterogeneous nature. In the future, it is estimated to analyse the parameters of yield, pollen sterility, cellular activity, and to work with identified forms with changes (in subsequent generations).

Keywords: bread winter wheat; mutagenic depression; epimutagen; mutagenesis; surviving; Triton X-305.

Introduction

The use of agents characterised by biodiversity in cultivated plants and particularly in cereal crops allow – within fairly short time – obtaining forms that either have new economic – valuable traits or have tolerance to negative factors, or have fundamentally new features that are uncommon (Abdoun et al., 2022). There are also alternative ways to obtain this material, but they are usually much longer and more time- and resource-intensive or they are significantly less effective for obtaining sufficient material for using its genetic purity (Vesali et al., 2017; Semenov et al., 2020). The study based on finding new factors of hereditary variability is particularly relevant due to the need of reducing the depression effects of the classic mutation agents, increasing the possibility of ignoring specific genotype-mutagenic impact (Liu et al., 2017; Li et al., 2019). An increasing importance is seen for substances that cannot directly cause the DNA changes but indirectly cause the necessary inherited changes, especially through the influence on the structure of the protein chromosome, the so-called epimutaggenic substances (Yakymchuk et al., 2022).

The use of a number of such substances showed they are generally less likely to cause a sharp decline in the earing, survival, are more conducive to the fertility of the plants, but they have also sufficiently altered the source material and cause improvements with high frequency. In addition, those agents cause a number of qualitatively new hereditary changes, which are not fully observed or may be partly and irregulary observed when applying more classic chemical supermutagens or ionizing irradiation (Xicun et al., 2016).

However, the use of such agents requires changes in the developed methodological approaches, claqrification of property variation boundaries under the impact of such factors, possibilities of obtaining specific features, range of practically significant genetic and selection-valuable concentrations, features of interaction with specific crops and boundaries of genotype-mutagenic interaction (Shu et al., 2013; Spencer-Lopes et al., 2018). The objectives of our research were the possible depressive effects of the Triton X-305 epimutachen factor and identifying key points in terms of obtaining the exact amount of plant material for further analysis and identification of forms with possible valuable changes. In this case, we studied the index of germination, survival and related physiological parameters of activity in critical periods of wintering and earing (photosynthetic activity), which determine the sample size for further work, and secondly, characterize the possibility of obtaining a full-fledged plant material for further scrutiny.

Materials and methods

The experiment has been conducted in the conditions of the experimental space of the Department of Breeding and Seedfarming of the Dnipro State Agrarian Economic University during 2021–2022. Wheat grains of soft winter-annual (1,000 grains in each treatment and control) were treated with a Triton-X-305 aqua solution in concentrations of 0.01%, 0.05%, 0.1% and 0.5%. Grain has been soaked with an exposition in 36 hours in accordance with the generally accepted method of processing chemical mutagens. These concentrations were determined according to earlier studies of analogue substances on grain crops.

The control was soaked in water (Shu et al., 2013; Spencer-Lopes et al., 2018). In total, 32 variants were sown (plot of 10 rows in each variant, width of the row-spacing 0.15 m, length of 1.5 m): varieties Podolyanka, Spivanka (domestic breeding), Altigo (Lemagrin, France), Courtot, Lyrik, Flamenko (INRA, France). The varieties were selected in order to maximize possible biodiversity of winter wheat (Shu et al., 2013; Spencer-Lopes et al., 2018).

The method of crop protection is generally accepted for the sub-humid area (Steppe of Ukraine).

We conducted the phlenological studies, assessed the overwintering of both visually and by determining the concentration of sugars in the node in meaningful period, determined the germination and survival of plants on the plots, conducted an assessment of photosynthetic activity during the earing period by the SPAD-502 appliance and an calculation to the concentration of chlorophyll (a+b) according to the generally accepted methodology using the formula $Chl = 10*M^{0.265}$, where M is the value of SPAD units (Vesali et al., 2017). Comparison of average values was carried out through factor analysis, grouping and evaluation of data was performed using discriminant analysis.

Results

First of all, the effect of mutagenic factors manifested in the germination and survival of winter wheat plants in the first generation (in subsequent generations, this effect has hardly manifested, and the mutagenic effect expressed in the availability and frequency of modified forms).

The data concerning the germination, survival at the beginning of winter and at the end of winter yield of winter wheat plants is provided for more successful genotypes characterized by significant stimulus effect at 0.01% Triton X-305 (TH-305) (Table 1) and less successful genotypes, higher level of depression (Table 2).

The variety of Spivanka, Altigo and Podolyanka has generally demonstrated similar dynamics of epimutagene with one exception (for Spivanka and Podolyanka) characterized by statistically significant stimulating effect ($F = 146.22$, $F_{0.05} = 7.70$, $P < 0.01$; $F = 84.76$, $F_{0.05} = 7.70$, $P < 0.01$). These are not characteristic features of Altigo, however, it has been described as having mild depression in germination ($F = 18.33$, $F_{0.05} = 7.70$, $P < 0.01$) and also undergoing stimulating effect compared with the control before and after winter ($F = 91.34$, $F_{0.05} = 5.56$, $P < 0.01$). The control of this variety is also characterized by high death of plants before overwintering, which is probably caused by numerous features ($F = 32.06$, $F_{0.05} = 3.88$, $P < 0.01$).

We discovered the non-significant death of plants for all TH-305 0.05% varieties between an emergence and before the winter ($F = 1.97$, $F_{0.05} = 3.88$, $P < 0.01$), for higher concentrations (0.1% and 0.5%), it was much more significant and statistical differences are more reliable ($F = 27.11$, $F_{0.05} = 3.88$; $P < 0.01$).

Table 1
Mutagenic depression in the first generation in germination and survival of more enduring varieties (x ± SD, n = 10)

Variant	Germination	Befor winter	Surviving
Spivanka	98.00 ± 1.00^{a}	91.33 ± 0.58^{a}	90.67 ± 0.58^{a}
Spivanka, TX-305 0.01%	96.33 ± 0.58^{b}	95.33 ± 0.58^{b}	94.67 ± 0.58^{b}
Spivanka, TX-305 0.05%	89.67 ± 0.58^{c}	88.67 ± 0.58^{c}	83.00 ± 1.01^{c}
Spivanka, TX-305 0.1%	81.33 ± 1.53^{d}	75.00 ± 2.65^{d}	62.67 ± 2.08^{d}
Spivanka, TX-305 0.5%	57.33 ± 5.69^{e}	56.00 ± 1.00^{e}	40.67 ± 1.15^{e}
Altigo	97.67 ± 0.58^{a}	88.33 ± 0.58^{a}	87.67 ± 0.58^{a}
Altigo, TX-305 0.01%	93.67 ± 0.58^{b}	92.00 ± 0.44^{b}	91.00 ± 1.06^{b}
Altigo, TX-305 0.05%	87.33 ± 0.58^{c}	86.33 ± 0.58^{c}	81.33 ± 1.53^{c}
Altigo, TX-305 0.1%	70.67 ± 2.08^{d}	69.33 ± 1.53^{d}	60.33 ± 7.57^{d}
Altigo, TX-305 0.5%	62.00 ± 2.65^{e}	61.02 ± 2.00^{e}	48.00 ± 3.61^{e}
Podolyanka	99.00 ± 1.00^{a}	92.33 ± 0.58^{a}	91.33 ± 0.58^{a}
Podolyanka, TX-305 0.01%	99.00 ± 1.15^{a}	95.33 ± 1.15^{b}	95.00 ± 1.00^{b}
Podolyanka, TX-305 0.05%	91.67 ± 1.15^{b}	90.33 ± 0.58^{c}	88.67 ± 0.58^{c}
Podolyanka, TX-305 0.1%	80.67 ± 2.52^{c}	75.00 ± 1.00^{d}	64.00 ± 1.00^{d}
Podolyanka, TX-305 0.5%	62.67 ± 1.53^{d}	59.00 ± 2.00^{e}	44.00 ± 4.00^{e}

Note: indicate significant differences at P < 0.05 by factor analyse; comparison in terms of one variety.

However, deaths of plants during winter were very significant for these concentrations in all cases, which is critical for mutagenic depression of winter crops in general ($F = 179.82$; $F_{0.05} = 3.88$; $P < 0.01$). It should be noted that the extreme concentration has been half-lethal for all the classes. Subsequent studies on the appearance of hereditary changes would allow to classify a dose efficiency in more appropriate way, while, according to growth and development indicators, we believe that the matching of gamma rays in 200 Gy (based on already conducted studies for Spivanka grade) is determined as depressive effect.

Therefore, Table 2 demonstrates that TH-305 was much more depressive for Courtot, Lyrik, Flamenko, especially for the first two. The winter period was particularly critical, while the death after the germination and before the winter was quite often not statistically significant except for the concentration of TH-305 0.5% ($F = 39.44$, $F_{0.05} = 3.88$, $P < 0.01$). For all three varieties, the winter has severely negatively affected the plant survival, meaningful death even under control, indicating the low adaptability of these genotypes to the extreme continental cultivation conditions.

Unlike previous varieties, TH-305 0.1% was half-lethal for Flamenko, and for Courtot. After winter, the half-lethal for 0.01% was even a sparing concentration of 0.01%. For Lyrik, it was half-lethal at 0.05% concentration. The extreme concentration for the last two varieties has already been critical and if in the autumn period, Courtot had a sufficient material (all of them had died in winter), Lyrik has already had very low germination. Thus, this varietyб already at the genetic levelб demonstrates the extreme sensitivity (affinity) to the action of the agent. In order to clarify how critical the winter hardiness of the variety was, we analyzed for the presence of sugars in the tillering node during winter period (Tables 3 and 4).

Firstly, less sensitive group (Table 3) is characterized by higher sugar content in the tillering node during all the analyzed periods. In general, in all cases, there was a dynamic of gradual decrease in the time of winter period and a rather significant decrease depending on the concentration used ($F = 4.10$, $F_{0.05} = 2.44$, $P < 0.05$). The more complete picture was given by the first and second measurement periods, in March, after winter, when the concentration of sugars decreased less. Characteristic stimulating effect was seen for the smallest epimutagen concentration.

Table 4 demonstrates a significantly lower sugar concentration for varieties are more sensitive to the agent. Therefore, sometimes, the difference in reliability between the concentrations is smoothed and not as clearly visible, furthermore they are ($F = 3.07$, $F_{0.05} = 2.44$, $P < 0.05$), the stimulus effect of TH-305 0.01% was only visible for Flamenko, the other two genotypes have already been depressed at this concentration.

In order to characterize the depression effect, the indicator of photosynthetic activity was investigated in a later critical period (Table 5 and 6). In general, it can be noted that variability in this indicator of domestic varieties is higher than foreign varieties, which sometimes leads to the impossibility to see with statistical significance the decrease (or stimulation) of this indicator depending on the concentration of epimutagen. It also complicates the overall problem of significantly lower variability of this trait in all varieties.

Table 2
Depression rates for growth and development in more sensitive varieties (x ± SD, n = 20)

Variant	Germination	Befor winter	Surviving
Courtot	92.00 ± 2.00^{a}	85,00 ± 1.03^{a}	76.67 ± 1.53^{a}
Courtot, TX-305 0.01%	91.67 ± 1.53^{a}	88.67 ± 0.58^{a}	25.33 ± 1.49^{b}
Courtot, TX-305 0.05%	83.00 ± 1.00^{b}	79.33 ± 0.58^{b}	20.67 ± 1.48^{c}
Courtot, TX-305 0.1%	62.67 ± 1.53^{c}	59.00 ± 1.06^{c}	12.00 ± 2.65^{d}
Courtot, TX-305 0.5%	49.05 ± 3.61^{d}	40.67 ± 1.53^{d}	3.33 ± 0.58^{e}
Lyrik	91.33 ± 1.53^{a}	89.33 ± 0.58^{a}	69.33 ± 3.06^{a}
Lyrik, TX-305 0.01%	81.00 ± 1.00^{b}	77.67 ± 1.53^{b}	69.33 ± 3.11^{a}
Lyrik, TX-305 0.05%	69.00 ± 4.36^{c}	62.67 ± 6.11^{c}	42.00 ± 3.61^{b}
Lyrik, TX-305 0.1%	30.00 ± 6.08^{d}	28.00 ± 1.00^{d}	11.00 ± 1.00^{c}
Lyrik, TX-305 0.5%	8.00 ± 6.24^{e}	4.67 ± 1.53^{e}	0.00 ± 0.00^{d}
Flamenko	95.33 ± 0.58^{a}	89.33 ± 0.58^{a}	81.33 ± 1.15^{a}
Flamenko, TX-305 0.01%	97.00 ± 1.00^{b}	94.00 ± 1.00^{b}	86.67 ± 1.53^{b}
Flamenko, TX-305 0.05%	83.33 ± 3.21^{c}	79.00 ± 1.00^{c}	72.33 ± 2.52^{c}
Flamenko, TX-305 0.1%	65.67 ± 3.21^{d}	59.67 ± 0.58^{d}	50.00 ± 1.00^{d}
Flamenko, TX-305 0.5%	53.67 ± 3.06^{e}	41.00 ± 1.00^{e}	37.33 ± 2.08^{e}

Note: significant differences at P < 0.05 by factor analyse; comparison in terms of one variety.

Table 3
Winter wheat varieties parameters during winter period (2021/2022 periods of vegetation dates) (x ± SD, n = 5); first group

Variety	BW	Content of sugars in tillering nod, %			AW
		11	02	03	
Spivanka	5.0	33.4 ± 0.4^{a}	29.7 ± 0.3^{a}	22.4 ± 0.4^{a}	5.0
Spivanka, TX-305 0.01 %	5.0	34.9 ± 0.3^{b}	31.3 ± 0.4^{b}	26.1 ± 0.3^{b}	5.0
Spivanka, TX-305 0.05 %	4.3	30.0 ± 0.4^{c}	27.6 ± 0.5^{c}	21.0 ± 0.3^{c}	4.0
Spivanka, TX-305 0.1 %	3.8	28.7 ± 0.6^{d}	25.9 ± 0.4^{d}	20.5 ± 0.5^{d}	3.0
Spivanka, TX-305 0.5 %	3.0	26.0 ± 0.5^{e}	23.1 ± 0.4^{e}	19.1 ± 0.5^{e}	2.8
Altigo	4.5	24.8 ± 0.3^{a}	22.7 ± 0.5^{a}	19.3 ± 0.4^{a}	4.5
Altigo, TX-305 0.01 %	5.0	28.4 ± 0.3^{b}	24.0 ± 0.4^{b}	20.2 ± 0.6^{a}	5.0
Altigo, TX-305 0.05 %	4.0	23.7 ± 0.4^{c}	21.5 ± 0.5^{c}	20.0 ± 0.5^{a}	3.8
Altigo, TX-305 0.1 %	3.5	22.2 ± 0.4^{d}	20.0 ± 0.3^{d}	19.3 ± 0.5^{a}	3.0
Altigo, TX-305 0.5 %	3.0	21.6 ± 0.5^{d}	19.2 ± 0.3^{e}	16.6 ± 0.4^{b}	2.8
Podolyanka	5.0	33.1 ± 0.4^{a}	27.4 ± 0.4^{a}	22.9 ± 0.4^{a}	5.0
Podolyanka, TX-305 0.01 %	5.0	34.7 ± 0.5^{b}	29.1 ± 0.5^{b}	24.5 ± 0.4^{b}	5.0
Podolyanka, TX-305 0.05 %	4.5	30.9 ± 0.3^{c}	26.1 ± 0.6^{c}	20.8 ± 0.3^{c}	4.0
Podolyanka, TX-305 0.1 %	3.5	28.1 ± 0.4^{d}	24.4 ± 0.3^{d}	19.2 ± 0.5^{d}	3.5
Podolyanka, TX-305 0.5 %	3.0	26.4 ± 0.5^{e}	22.0 ± 0.5^{e}	17.3 ± 0.5^{e}	3.0

Note: BW – evaluation before winter period [points]; AW – evaluation after winter period [points]; significant differences at P < 0.05 by factor analyse; comparison in terms of one variety.

Table 4
Winter wheat varieties parameters during winter period (2021/2022 periods of vegetation dates) (x ± SD, n = 5); second group

Variety	BW	Content of sugars in tillering nod, %			AW
		11	02	03	
Courtot	4.0	22.1 ± 0.4^{a}	17.9 ± 0.4^{a}	16.9 ± 0.5^{a}	4.0
Courtot, TX-305 0.01%	4.0	20.9 ± 0.5^{b}	16.7 ± 0.4^{a}	15.1 ± 0.8^{b}	4.0
Courtot, TX-305 0.05%	3.0	14.2 ± 0.4^{c}	11.9 ± 0.6^{b}	9.9 ± 0.4^{c}	3.0
Courtot, TX-305 0.1%	2.0	11.3 ± 0.4^{d}	8.7 ± 0.7^{c}	8.6 ± 0.6^{d}	2.0
Courtot, TX-305 0.5%	1.0	10.3 ± 0.3^{e}	non	non	1.0
Lyrik	4.0	18.6 ± 0.5^{a}	12.6 ± 0.5^{a}	11.1 ± 0.3^{a}	4.0
Lyrik, TX-305 0.01%	4.0	16.5 ± 0.4^{b}	11.2 ± 0.5^{b}	10.0 ± 0.5^{b}	3.8
Lyrik, TX-305 0.05%	3.0	13.4 ± 0.4^{c}	10.9 ± 0.6^{b}	9.1 ± 0.5^{b}	3.0
Lyrik, TX-305 0.1%	2.0	11.3 ± 0.3^{d}	10.2 ± 0.5^{b}	7.6 ± 0.7^{c}	2.0
Lyrik, TX-305 0.5%	1.0	8.7 ± 0.5^{e}	non	non	1.0
Flamenko	4.0	22.2 ± 0.6^{a}	19.5 ± 0.5^{a}	16.2 ± 0.4^{a}	4.0
Flamenko, TX-305 0.01%	4.5	24.3 ± 0.4^{b}	20.8 ± 0.7^{b}	20.6 ± 0.7^{b}	4.5
Flamenko, TX-305 0.05%	4.0	21.5 ± 0.3^{c}	19.1 ± 0.5^{a}	16.0 ± 0.3^{a}	3.8
Flamenko, TX-305 0.1%	3.0	20.4 ± 0.5^{d}	18.6 ± 0.5^{ac}	14.9 ± 0.4^{c}	3.0
Flamenko, TX-305 0.5%	2.0	18.2 ± 0.6^{e}	16.1 ± 0.7^{d}	14.6 ± 0.5^{c}	2.0

Note: BW – evaluation before winter period [balls]; AW – evaluation after winter period [points]; significant differences at P < 0.05 by factor analyse; comparison in terms of one variety.

However, the effect was depressive and quite significant in general, although not as extreme as in the situation with indicators of winter hardiness. The trait was less variable, stimulating effect is possible for TH-305 0.01%, but it is not always noted. This feature was especially successful in terms of classification of individual concentrations, in the varieties of Altigo and Flamenko. Lyrik variety was characterized by an extreme decline after the application of the first concentrations.

Thus, this trait showed a substantial difference between the genotypes in the responsiveness to the epimutagen and generally depended on the genotype of the original variety ($F = 6.02$, $F_{0.05} = 2.45$, $P < 0.05$). This feature is important for characterizing the effect at a critical phase of the plants, the earing, when the activity of the photosynthetic element is crucial in the formation of grain and, subsequently, the availability of the material for further research.

As a result of factor analysis (Table 7), we have found that the epimutagen concentration had influenced such parameters of study as germination, survival, concentration of sugars in the tillering node before and immediately after the winter period (as an integrative indicator of winter hardiness), photosynthetic activity.

Table 5
Parameters of photosynthetic activity (x ± SD, n = 5); first group

Variant	Soil plant analysis development (SPAD)	Chl, μmol/m^2
Spivanka	50.16 ± 2.61[a]	664.12 ± 19.46
Spivanka, TX-305 0.01%	50.40 ± 2.45[a]	669.60 ± 18.52
Spivanka, TX-305 0.05%	47.52 ± 2.63[b]	605.48 ± 19.59
Spivanka, TX-305 0.1%	47.50 ± 2.36[b]	605.04 ± 18.02
Spivanka, TX-305 0.5%	44.26 ± 1.51[b]	537.27 ± 13.07
Altigo	52.18 ± 0.63[a]	711.10 ± 7.67
Altigo, TX-305 0.01%	55.98 ± 0.68[b]	804.55 ± 7.99
Altigo, TX-305 0.05%	50.42 ± 0.64[c]	670.06 ± 7.75
Altigo, TX-305 0.1%	48.06 ± 0.42[d]	617.22 ± 6.20
Altigo, TX-305 0.5%	46.88 ± 0.31[e]	591.72 ± 5.42
Podolyanka	47.32 ± 1.50[a]	601.16 ±12.99
Podolyanka, TX-305 0.01%	50.94 ± 1.44[b]	682.04 ± 12.64
Podolyanka, TX-305 0.05%	45.44 ± 0.99[a]	561.43 ± 9.93
Podolyanka, TX-305 0.1%	43.90 ± 0.98[ac]	530.02 ± 9.89
Podolyanka, TX-305 0.5%	41.74 ± 1.45[cd]	487.65 ± 12.69

Note: significant differences at P < 0.05 by factor analyse; comparison in terms of one variety.

Table 6
Parameters of photosynthetic activity (x ± SD, n =5); second group

Variant	Soil Plant Analysis Development (SPAD)	Chl, μmol/m^2
Courtot	49.44 ± 0.47[a]	647.82 ± 6.56
Courtot, TX-305 0.01%	49.12 ± 0.26[a]	640.65 ± 5.00
Courtot, TX-305 0.05%	44.20 ± 0.45[b]	536.06 ± 6.47
Courtot, TX-305 0.1%	43.58 ± 0.52[b]	523.61 ± 6.91
Courtot, TX-305 0.5%	43.60 ± 0.42[b]	524.01 ± 6.22
Lyrik	50.72 ± 0.41[a]	676.96 ± 6.19
Lyrik, TX-305 0.01%	44.22 ± 0.34[b]	536.46 ± 5.66
Lyrik, TX-305 0.05%	43.48 ± 0.37[b]	521.62 ± 5.87
Lyrik, TX-305 0.1%	42.08 ± 0.58[c]	494.19 ± 7.34
Flamenko	55.74 ± 0.39[a]	798.45 ± 6.02
Flamenko, TX-305 0.01%	56.78 ± 0.49[b]	825.08 ± 6.74
Flamenko, TX-305 0.05%	51.30 ± 0.76[c]	690.40 ± 8.50
Flamenko, TX-305 0.1%	46.72 ± 0.29[d]	588.31 ± 5.22
Flamenko, TX-305 0.5%	44.90 ± 0.34[e]	550.30 ± 5.63

Note: significant differences at P < 0.05 by factor analyse; comparison in terms of one variety.

In turn, the genotypes quite differed in the survival rates, concentration of sugars in the tillering node before the winter, photosynthetic activity. The other parameters in this case do not provide additional necessary information. This is confirmed by the values of variables of the discriminant analysis (Table 7).

But even though a substantially smaller number of parameters in our research depended on the genotype of the original variety, Table 8 shows the higher classification capability for objects to identify mutagenic depression (ranging from 80 to 100, depending on the genotype).

Table 7
Factor loadings (unrotated) and discriminant function

Parameter	Concen-tration	Genotype	Wilks'-lambda	F_{remove} (5.20)	P
Germination	–0.866*	–0.440	0.018	14.07	< 0.01
Befor winter	–0.692	0.049	0.010	4.90	< 0.01
Surviving	–0.913*	–0.851*	0.014	8.08	< 0.01
CS 11	–0.857*	0.877*	0.016	9.64	< 0.01
CS 02	–0.898*	0.404	0.002	2.23	0.08
CS 03	0.648	0.361	0.008	2.64	0.06
SPAD	–0.850*	–0.893*	0.016	9.33	< 0.01
Explenation variants	4.752	1.976	–	–	–
Non-explanation	0.678	0.198	–	–	–

Table 8
Resaults of classification for genotypes (part of objects by parameters from previous table in model for such genotype)

Genotype	Objects in model, %
Spivanka	100.0
Altigo	80.0
Podolyanka	80.0
Courtot	80.0
Lyrik	83.3
Flamenko	100.0
Total	86.7

Factor space analysis showed good positions of Flamenko and Spivanka, and worse positions for the rest varieties. However, all classes fall into a model with high level of relevance.

Figure 1 shows the position in factor space of all the studied varieties. It can be noted that the domestic and foreign varieties are actually located in two different groups, the transitional value belongs to the Altigo.

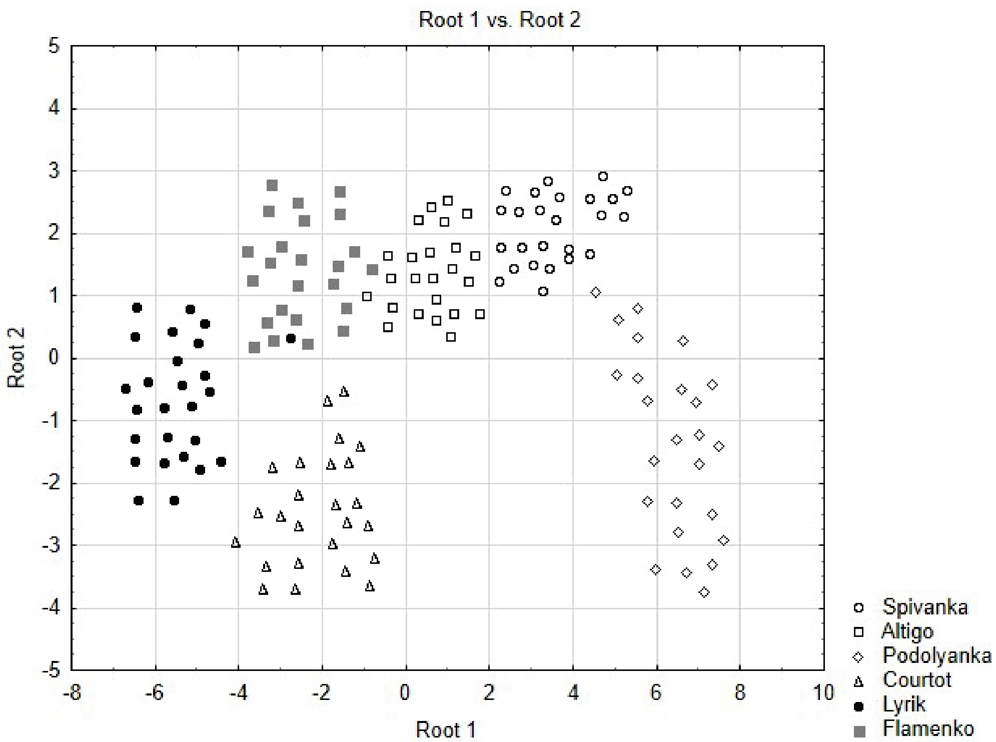

Fig. 1. Classification by canonical roots

It is quite clear that two groups of varieties are separated, one comprising varieties Spivanka and Podolyanka, the other including varieties Courtot, Lyrik, Flamenko. The intermediate value is Altigo.

It should be noted that the determining factor in this case was the adaptability of a particular variety to the environmental conditions for which the varieties of the first group had been created. However, it is not possible to say that different genotypes are significantly mixed in the analysis space. They all form a rather clear, separate set of objects observed.

Discussion

For crops in general, the study of the forming process of various agents has always noted that a critical indicator of using both individual factors and doses or concentrations is the amount of the surviving plant material for further research with the aim of selection breeding and obtaining genetic valuable material (Nazarenko et al., 2019; Nazarenko, 2020; OlaOlorun et al., 2021). For this narrow point, a combination of two points is of particular importance. Firstly, it is genetically conditional resistance to these factors (there are several possible systems that are responsible for adaptive response in this area), and secondly these are the adverse effects of external factors, which depend primarily on the adaptability of this material in specific cultivation conditions and is especially important for winter crops (Jaradat, 2018; Prabhu, 2019). However, it is a very promising task to find both new agents that cause the necessary inherited changes and research of their effect on the maximum possible amount of material, with the involvement of domestic, local genetic resources and comparison of the gained effect with the established world's leading centres for genetic improvement of these cultures (Lykhovyd, 2021; Yali & Mitiku, 2022).

In some cases, such studies have helped to identify fundamentally new mechanisms for adaptive reactions to adverse mutagenic effects (Liu et al., 2017; Li et al., 2019). The most negative effects are primarily for the first generation in case of one-time exposure (with prolonged exposure, the value of the generation decreases, but for chronic influence, very different mechanisms of genetic regulation are involved) (Nazarenko, 2015; Mamenko & Yakymchuk, 2019). The so-called small effects are of particular importance, they lead to significant changes in the genotype of this material (not always through changes directly to DNA, as well as epigenetic mechanisms for expression control). In this regard, substances that are less traumatic to the basis of heredity are of particular importance (Nazarenko & Izhboldin, 2017; Oney-Birol & Balkan, 2019).

The possibility of the growth and development stimulating effects of one of these substances has been noted for the first time, which has not been previously noted for epimutagens. However, the negative impact of increased concentration on traditional parameters has been present still. The possible new critical parameter forthe depression in the first generation has been set, that is the intensity of photosynthesis (Vesali et al., 2017; Jaradat, 2018). Despite the varied nature of the first generation of mutagenic depression at all levels, this part has not been studied separately (Juhi et al., 2019; Cann et al., 2022).

However, the level of such activity in the critical phase for grain formation in spike crops may be crucial for the future productivity and, as a result, the yield of the sample obtained (that is critical when registering modified forms in subsequent generations) (Ariraman et al., 2018; Asif, 2020). In addition, there are few quantitative limits of accounting the adverse activity parameters. It is not necessary to measure winter hardiness to the critical February period. Although this is not the point of resumption of active growth processes in winter wheat, there is no need of accounting death in the autumn period (Hiroyasu, 2018; Essam et al., 2019).

At least in one case, the studied agents showed extreme affinity with the treated material, which caused a significant increase of its adverse value (which has not been previously noted) (Mangi et al., 2021), in the other case, it has been more critical in combination with a more flexible overall adaptability to the cultivation conditions (Hong et al., 2022), that is quite natural.

Conclusion

The use of fundamentally new types of chemicals as agents of the cereal biodiversity induction is an opportunity to obtain not only new changes (or the frequency of increase/decrease of the already known ones) traits of crop, but also allows to make a point-adjustment of the genome in the future and thus to form a new plant architecture, model of the variety. The principal point, however, has always been that depressive effects were significantly limiting the range of concentrations of mutagenic factors. The use of epigenetic agents, with the possibility of changing the traits primarily due to the changes in protein skeleton by chromosome, in this case, it is profitable primarily in terms of low mutagenic depression. However, there is the problem of the necessary changes with sufficient frequency in subsequent generations, therefore, our future research will be dedicated to the determining and accounting them. In addition, genotypical dependence in the operation of such factors is very high, since it has already been seen in the first cycle of research.

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