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***Mykola NAZARENKO [1], Olexandr IZHBOLDIN [2], Olena IZHBOLDINA*[3]***

# USE OF GAMMA IRRADIATION TO OBTAIN NEW FORMS OF WINTER WHEAT BASED ON LOCAL VARIETIES

## SUMMARY

The research objective was to identify the peculiarities of the mutational activity induced by different doses of gamma irradiation in local winter wheat varieties based on the indicators of induced mutations spectrum in the second to fourth generation, to identify new high-potential forms in terms of grain productivity and quality, to identify variable components in forming such traits for a more controlled action by mutagenic agents. It has been established that a positive mutational process is essential for many useful traits, depending mainly on the original form genotype. The process has been proven to be a reliable permanent source of variability for the local genetic resources in terms of certain traits of economic value to obtain modern highly productive and highly adaptive potential forms. The regularity of the beneficial mutational process has been described, which allows to make the process of using this type of variability in order to obtain new material with the required potential more manageable, reliable and predictive.

**Keywords**: winter wheat, gamma irradiation, mutation spectrum, mutagenesis.

## INTRODUCTION

The effect of physical mutagens on plants usually results in hereditary mutations, which can be beneficial for practical use in agriculture. Even a small single exposure significantly corrects the vitality and heredity of the plant (Daryanto *et al*, 2017).

[1]Mykola Nazarenko, Department of Plant Breeding and Seeds Production, Dnipro State Agrarian and Economic University, 49600, Dnipro, UKRAINE,
[2]Olexandr Izhboldin, Department of Plant Production, Dnipro State Agrarian and Economic University, 49600, Dnipro, UKRAINE,
[3]Olena Izhboldina (corresponding author: research.team.ddaeu@gmail.com), Department of Livestock Production Technology, Dnipro State Agrarian and Economic University, 49600, Dnipro, UKRAINE.
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Gamma irradiation is a popular mutagen of the kind, used for both mutational improvement and studies on the effects of mutagens on living organisms (including model objects). The overwhelming number of successful obtainment of practically valuable varieties of agricultural crops is due to the use of gamma irradiation, which, taking into account the high intensity of relevant research, is still widely used both in traditional breeding improvement, and for the studies of systems of genetic control of certain features and obtaining of fundamentally new architecture of the stem and head in wheat. Thus, in the 21st century, 217 varieties were created by irradiation: China – 93, the USA – 18, Russia and Iraq – 13, India – 10, Bangladesh and Pakistan – 9, Vietnam – 5, Poland – 2, Japan and Korea – 7. 62.2% of varieties were created in Asia, 11.7% – in Europe (Pandit *et al*, 2021).

Some researchers believe that it is better to use high doses of gamma irradiation (within the range of 200–300 Gy). Existing FAO/IAEA statistics (Prabhu, 2019) partially supports the statement. Genetic improvement using different doses of gamma irradiation has been successful in creating productive mutants, resistant to disease and abiotic stress. Gamma irradiation quite often leads to drastic morphological changes in organisms. It is mutants with dramatic phenotype changes that should have beneficial changes in the content of valuable biochemical substances (Žofajová *et al*, 2017).

The effect of gamma irradiation is characterized by pronounced mutations, a high number of morphoses and genocopies. Although it is not the best choice in terms of increasing mutational activity, gamma irradiation of dry seeds is more effective in view of subsequent obtaining of mutational material, which has become an established practice worldwide. The increase in frequency and spectrum in the case of other subjects is insignificant due to further problems (Shan *et al*, 2018).

Studies on the experimental mutagenesis of cereal crops in South-East Asia, according to international scientific cooperation programs, have resulted in over 30 new varieties of crops obtained through the use of gamma irradiation. Physical mutagens are used more frequently and more efficiently (Tsenov *et al*, 2015; Liu *et al*, 2017).

The doses of gamma irradiation are considered optimal, when the seed similarity is 70-80%, and the survival of plants is 80-90%. That is, gamma irradiation of 100 - 150 Gy (Nazarenko *et al*, 2019b). It is believed that low-dose gamma irradiation changes the ratio and interaction of various valuable traits in crops quite significantly, and generally increases productivity, quality, and adaptive potential (Katyal *et al,* 2016; Datsu *et al,* 2020). As a result, mutants were obtained with practically valuable traits in terms of yielding, with an increased content of essential amino acids and microelements. When using small doses of gamma irradiation during certain periods of growth and development, when a new trait is formed and with the corresponding effect of environmental factors, a mutation occurs as a process of formation and leads to stable and practically valuable traits (Polatovich *et al,* 2021).

The main purpose was to identify the peculiarities of the level of mutability for local winter wheat varieties based on the indicators of mutations rate and spectrum at the second - fourth generations, the possibilities of local genetic sources for improvement through mutation breeding methods.

The main tasks were: to study the indicators of the rate of several value groups of mutations, their availability in the spectrum of mutations for local winter wheat varieties Komertsiina and Spivanka in the second - fourth generations; to identify the effect of individual doses of gamma-irradiation on the spectrum of induced changes, genotype and mutagenic interaction; to analyze the mutation spectrum, identify its key components and the possibility of obtaining new agricultural- and genetic-value forms; to identify the high-productive and high-qualitive (protein content and protein components) lines as future commercial varieties or components for hybridization.

## MATERIAL AND METHODS

The research was carried out on the experimental fields of the Educational and Scientific Center of the Dnipro State Agrarian and Economic University in 2015-2021. The experimental areas have a homogeneous cover, consisting of ordinary low-humus, leached, medium-loamy black soil on a loamy soil. The content of nitrogen (according to Tiurin) during the years of research has not exceeded 3–5 mg, mobile phosphorus (according to Chyrykov) – 20-30 mg, exchange potassium (according to Chyrykov) – 20-35 mg per 100 g of dry soil.

The experimental field is located in the Dniprovskyi district of the Dnipropetrovsk region, Ukraine, which is the northern warm and insufficiently wet area. Its climatic resources are characterized by the following indices: hydrothermal coefficient is >0.9, precipitation rare during the growing season – 250-280 mm, the annual amount of precipitation – 450-490 mm, temperature sum for the period with the temperatures above 10°C – about 2,900°C.

As a material for the study, the following varieties were used: local varieties of Komertsiina and Spivanka (Dnipro State Agrarian and Economic University), being the material that fully meets the conditions of the region (Northern Steppe of Ukraine). Dry seeds were exposed to gamma irradiation of 100, 150, 200, 250, 300 Gy. Doses of gamma irradiation are standard for the irradiation spectrum used in the experimental mutagenesis of this culture to increase the variability of the starting material.

The variability rate was calculated using the formula

$Pv = \alpha \bullet \gamma$,

where $Pv$ is the variability of the variant;

$\alpha$ is the ratio of the number of mutations to the total number of families in the variant;

$\gamma$ is the number of types of changed traits in the variant.

The seeds of these varieties were treated at the gamma-ray unit of the Nuclear Research and Training Centre of the Department of FAO/IAEA Joint

Division of Nuclear Techniques in Food and Agriculture (Austria, Freiburg), with gamma rays of the Co60 radioactive source, the capacity of the unit is 0.048 Gy/s.

In the second and third generation, we studied the mutations visually and by yield at hand sowing by families (1-3-row plots, row spacing of 0.15 m, row length of 1.5 m), carried out inheritance studies, productivity and structural analysis of selected mutant strains (plot area of 5 – 10 $m^2$, 1-3-time repeatability). The mutation rate was calculated as a ratio of mutant cases to the total number of families in the second generation in percent, the variability was measured as a ratio of changed traits to the proportion of mutant families in the second generation – each mutant case as an individual phenomenon. Mutant strains (25 plants each) were analyzed to measure yield parameters. The area of the plots was 5–10 $m^2$ depending on the year of the experiment, the repetition was 1-2 times, the standard – every 20 numbers. Two performance and quality reference groups were seeded – the original form and the national standard of Podolyanka variety. The protein content in wheat grain was measured on the Spektra RT device, the content of glutenins and gliadins by liquid chromatography on the RP-HPLS device

Statistical processing of the obtained results was carried out using the discriminant analysis, the quality of the mean difference was assessed by factor analysis. The standard package of the Statistic 10.0 application was used.

## RESULTS AND DISCUSSION

Indicators of variability of families and lines in $M_{2\text{-}4}$ induced by different doses of gamma rays, are given in Table 1 (total rate of mutations, number of changed traits, variability). In the Komertsiina variety, the mutation rate ranged from 8.40% (gamma rays, 100 Gy) to 30.00% (gamma rays, 250 Gy) with a 1.20% control (spontaneous mutation rate). In the Spivanka variety, 6.40% (gamma rays, 100 Gy) to 31.67% (gamma ray, 250 Gy) at 0.80% of spontaneous mutations in the untreated reference group. As can be seen from the growing mutation rate in both varieties, it occurs gradually, but in general in the Spivanka variety, the rate is significantly lower than in the Komertsiina variety, with a sharp increase in this parameter at a dose of 250 Gy (almost 60% of the previous number), while in the Komertsiina variety the mutation rate remains mostly unchanged at doses of 200–250 Gy and is not characterized by peak increases.

The number of types of changed traits within the entire dose range is higher, in contrast, in the Spivanka variety, which characterizes a significant increase in the spectrum of mutations for this genotype, while in the Komertsiina variety the number of mutants in terms of individual traits increases significantly. However, the overall spectrum is substantially scarce. Depending on the specific content of the range of changes, this may mean that at a high level of variability in terms of economic value, this variety may be more viable directly for obtaining economically valuable forms. Whereas the Spivanka variety is more effective in producing collections of genetically valuable traits, followed by use for improvement through combinatorial variability. In any case, in the Komertsiina variety, the number of types of changed traits decreases at increasing the gamma irradiation doses, while in the Spivanka variety, the spectrum, on the contrary, expands to a dose of 150 Gy, followed by a decline in doses of 200–250 Gy.

Table 1. Mutation rate and variability of winter wheat due to the action of gamma irradiation

| Variety | Gamma ray dose | | | | |
|---|---|---|---|---|---|
| | Control | 100 Gy | 150 Gy | 200 Gy | 250 Gy |
| Rate | | | | | |
| Komertsiina | 1.20±0.11 | 8.40±0.62[b] | 13.56±1.05[c] | 29.17±1.41[d] | 30.00±1.69[d] |
| Spivanka | 0.80±0.11[a] | 6.40±0.53[b] | 10.75±0.92[c] | 19.00±1.14[d] | 31.67±1.54[e] |
| Modified Traits | | | | | |
| Komertsiina | 4[a] | 21[b] | 18[b] | 15[c] | 11[d] |
| Spivanka | 4[a] | 24[b] | 28[b] | 24[c] | 15[d] |
| Variability | | | | | |
| Komertsiina | 0.05[a] | 1.76[b] | 2.45[c] | 4.38[d] | 3.30[e] |
| Spivanka | 0.03[a] | 1.54[b] | 3.02[c] | 4.56[d] | 4.74[d] |

*Note: The difference is statistically significant at P0.05 taking into account the Bonferroni correction*

The variability rate, as a complex indicator of genotype mutability due to a wider spectrum, is higher in the Spivanka variety, although not always significantly, and increases constantly with increasing dose, although not always significantly (250 Gy dose). The variability in the reference group is negligible, further indicating the spontaneous nature of the mutations obtained.

According to the results of factorial analysis, it was found that only the "dose" parameter was affected by the overall rate of mutations ($F=29.51$; $F_{critical}=6.39$; $P=0.01$). That is, despite significant differences, the nature of the variety ($F=1.89$; $F_{critical}=7.71$; $P=0.24$) did not in any way affect this indicator and the differences as a result of different doses, which is not enough to assess the genotype and mutagenic interaction factor as significant as a whole.

The index of variability showed that changes in frequency together with the differences in the breadth of the mutation spectrum were already significantly depended not only on the dose applied ($F=30.06$; $F_{critical}=6.39$; $P=0.01$), but also on the genotype ($F=9.76$; $F_{critical}=7.70$; $P=0.03$) – that is, on the grade of the starting material. The effect of the dose difference on mutational variability in both cases remains sound and significant.

In terms of the spectrum of action of gamma rays, 33 types of changed traits have been identified (which basically is not that much for the action of gamma irradiation as a mutagen of systemic, nonspecific action) and classified into the following groups: I. Stem and leaf structure mutations – all changes in stem and leaf morphometry and morphology. 1 Thick stem. 2. Thin stem. 3.

High-stem. 4. Short-stem. 5. Semi-dwarf. 6. Dwarf. 7. Intense epicuticular wax accumulation. 8. Mild epicuticular wax accumulation. II. Mutations in grain colour and structure. 9. Large-size grain. III. Mutations in spike colour and structure. 10. Awned spike. 11. Awnless spike. 12. Long spike. 13. Loose spike. 14. Cylindrical spike. 15. Spindle-shaped spike. 16. Compact spike. 17. Large-size spike. 18. Small-size spike. 19. Half-awned spike. 20. Rigid spike. 21. Club-shaped spike. 22. Arrow-shaped spike. 23. Anthocyan awns. IV. Altered physiological signs of growth and development. 24. Sterility. 25. Early ripeness. 26. Late ripeness. V. Mutations in grain productivity and quality. 32. Productive. 33. Forms with high tillering capacity. VI Systemic mutations are mutations beyond the systematic features specifically attributed to common winter wheat and more are more peculiar to related forms. 27. Square-head spike. 28. Speltoid spike. 29. Subcompactoid. 30. Compactoid. 31. Spherococcoid.

According to the results of the discriminant analysis (Table 2, only significant traits are given), the following key features can be distinguished, which are standard for both varieties: high-stem, short-stem, semi-dwarfs, intense wax accumulation, mild wax accumulation, awned spike, awnless spike, long spike, large-size spike, sterility, late ripeness, early ripeness, tillering capacity, productive, speltoid spike (a single systemic feature), a total of 15 traits from 33.

Table 2. Classification matrix by canonical roots

| Criteria | Availability in the model | | | Percentage of classification | |
|---|---|---|---|---|---|
| | Wilks' lambda λ | $F_{critical}$ (3.02) | p-level | Komertsiina | Spivanka |
| high-stem | 0.32 | 1.96 | 0.01 | 100.0 | 100.0 |
| short-stem | 0.25 | 2.13 | 0.01 | 79.0 | 88.0 |
| semi-dwarf | 0.20 | 2.86 | 0.02 | 21.0 | 70.0 |
| intense epicuticular wax accumulation | 0.24 | 2.22 | 0.01 | 100.0 | 100.0 |
| mild epicuticular wax accumulation | 0.19 | 2.91 | 0.03 | 85.0 | 79.0 |
| awned spike | 0.18 | 2.95 | 0.04 | 73 | -- |
| awnless spike | 0.18 | 2.97 | 0.04 | -- | 60.1 |
| long spike | 0.18 | 2.90 | 0.04 | 70.0 | 61.0 |
| large-size spike | 0.18 | 2.94 | 0.04 | 61.0 | 58.0 |
| sterility | 0.17 | 2.99 | 0.05 | 33.0 | 67.0 |
| late ripeness | 0.21 | 2.72 | 0.02 | 100.0 | 100.0 |
| early ripeness | 0.18 | 2.98 | 0.04 | 79.0 | 76.0 |
| tillering capacity | 0.18 | 2.94 | 0.04 | 67.0 | 64.0 |
| productive | 0.18 | 2.94 | 0.04 | 61.0 | 58.0 |
| speltoid spike | 0.17 | 3.01 | 0.05 | 58.0 | 67.0 |
| Average | -- | -- | -- | 68.2 | 72.9 |

Classification capabilities were analyzed in terms of significant features for individual genotypes (since awnless forms are only available in the Spivanka variety, awns are a mutation for the Komertsiina variety, as well as to detect genotype specificity in the gamma irradiation).

According to the above data, such features as a semi-dwarf and sterility fall out of the classification model for the Komertsiina variety. For the Spivanka variety, the classification significance of all traits is maintained, however with some minor changes. In general, the chances of modeling the mutation process for the Spivanka variety are slightly higher, but not significantly.

The greatest classification ability is found in such signs as plant height mutations (primarily tall-stalked), changes in the period of ripeness and wax accumulation. Of these, short-stalked and early-ripeness mutations are of practical importance.

11 viable mutant lines (third to fifth generation) were tested for yield, elements of its structure and grain quality. 6 lines were obtained from Spivanka variety and 5 from Komertsiina variety.

Data on the three-year yield test are given in Table 3. As we can see, only the lines (except line 203) that exceeded the Podolyanka variety standard during the test were selected.

Table 3. Yielding capacity of agrocenoses of mutant strains of common winter wheat during the experiment

| Genotype | 2018 | 2019 | 2020 | Average | +/- to standard |
|---|---|---|---|---|---|
| | t/ha | | | | |
| Podolyanka, st. | 5.23±0.09 | 5.42±0.07 | 7.89±0.12 | 6.18±0.10 | |
| 26 | 7.39±0.15* | 6.05 ±0.09* | 8.11±0.16 | 7.18±0.14* | 1.00 |
| 45 | 7.51±0.16* | 6.22±0.13* | 8.09±0.15 | 7.27±0.13* | 1.09 |
| 123 | 7.22±0.11* | 6.10±0.08* | 8.13±0.15* | 7.15±0.14* | 0.97 |
| 152 | 7.11±0.15* | 6.09±0.08* | 8.15±0.14* | 7.12±0.14* | 0.94 |
| 178 | 7.01±0.13* | 6.00±0.07* | 8.69±0.17* | 7.23±0.15* | 1.05 |
| 179 | 7.61±0.17* | 6.31±0.09* | 8.19±0.16* | 7.37±0.15* | 1.19 |
| 181 | 6.40±0.09* | 6.22±0.08* | 8.22±0.18* | 6.95±0.13* | 0.77 |
| 203 | 6.09±0.08* | 5.92±0.07* | 7.17±0.14 | 6.39±0.11 | 0.21 |
| 213 | 6.44±0.09* | 6.12±0.08* | 7.43±0.15 | 6.66±0.13* | 0.48 |
| 214 | 6.65±0.10* | 6.14±0.08* | 7.32±0.14 | 6.70±0.13* | 0.52 |
| 262 | 6.43±0.09* | 6.36±0.09* | 8.29 ±0.16* | 7.03±0.14* | 0.85 |
| $HIP_{0.05}$ | 0.22 | | | | |

** - statistically significant difference from the Podolyanka standard at $P_{0.05}$*

However, under optimal conditions (the most successful for the fulfillment of productive potential) in 2020, some lines formed yields at the standard level, which indicates their reference to a semi-intensive type with wider variability limits and that they are hardly better in terms of productivity than the original lines (for lines originating from the Komertsiina variety – lines 203, 213, 214) or are even worse (for lines originating from the Spivanka variety – lines 26 and 45). Thus, the lines 123, 152, 178, 179, 181, 262 can be considered more successful and recommended as the top priority. 4 lines are derived from the Spivanka variety and 2 from the Komertsiina variety. Thus, from the standpoint of assessing variability in terms of productivity trait, the use of Spivanka variety as the original form was more successful. This once again proves that it is the greater degree of variability and perfection in that particular trait that are more important factors in improving a certain line.

The results of factor analysis according to the dispersion analysis scheme confirm this fact. Thus, the genotype factor ($F=4.66$; $F_{critical}=4.11$; $P=0.02$) was significant, however, the year factor ($F=70.35$; $F_{critical}=3.44$; $P=0.01$), which caused a significantly greater proportion of dispersion in productivity variability, turned out to be more important.

Above all, this indicates the achievement of the necessary contrast and variability of the conditions of the years, which made it possible to fully analyze this trait. It also proves that weather conditions still remain the main limiting factor and it is impossible to significantly compensate for their effect solely on account of genetically determined adaptability.

Factor analysis proved that it was the interaction of the conditions of the year and the variety genotype that led to the differentiation of the original material, and showed that the factor of the original material genotype plays essential part, but it is obviously difficult to identify this role in more detail.

It was decided to analyze the elements of the yield structure within the framework of the study and by detailing the mechanism of agrocenoses productivity at the level of individual elements, to carry out a more detailed factor analysis to identify the priorities of factors and establish the most determinative aspects. The synergy of individual economic features was also interesting in the context of formation of the total yield and possible changes in the model of influence of individual traits (while the Spivanka variety is more oriented to productive tillering capacity, the Komertsiina variety – to grain content and filling of the main spike).

To determine the factors increasing yields, its structural analysis was performed (Table 4) by the following indicators: height of plants, productive tillering capacity, number of main spike grains and grain weight, plant grain weight, thousand kernel weight (TKW). As a result, it was found that in all productive lines, the increase in yield was influenced primarily by the increase in TKW and the grain weight of the plant, which was less than the grain weight of the main spike. As we can see, there were changes in the formation partly for each of the two original forms due to individual traits of the total yield at the level of the grain weight of the plant and the grain weight of the spike.

Table 4. The main indices of the yield capacity structure of mutant strains of common winter wheat

| Line, variety | Height of plants | Productive tillering capacity | Number of grains per main spike | Grain weight per main spike | Grain weight per plant | Thousand kernel weight |
|---|---|---|---|---|---|---|
| | cm | | pcs. | g | | |
| Podolyanka | 103±2.0 | 4.0±0.1 | 36.5±1.6 | 1.9±0.2 | 4.3±0.2 | 50.2±1.0 |
| 26 | 83.8±2.1* | 3.9±0.1 | 42.2±2.4* | 2.4±0.2* | 4.9±0.3 | 51.1±0.9 |
| 45 | 82.4±2.1* | 3.6±0.1 | 38.1±2.4 | 2.5±0.2* | 4.4±0.3 | 52.9±0.9* |
| 123 | 74.3±2.1* | 3.6±0.1 | 42.6±2.4* | 2.0±0.2 | 4.9±0.3* | 52.3±0.9* |
| 152 | 76.5±2.0* | 4.0±0.1 | 38.7±2.4 | 2.2±0.2 | 5.1±0.3* | 53.1±0.9* |
| 178 | 74.7±2.0* | 3.8±0.1 | 37.5±2.4 | 1.9±0.2 | 5.2±0.3* | 50.9±0.9 |
| 179 | 59.4±2.0* | 3.7±0.1 | 37.2±2.4 | 1.7±0.2 | 4.6±0.3 | 52.4±0.9* |
| 181 | 102.2±1.5 | 3.4±0.1 | 38.9±1.8* | 2.3±0.2* | 4.7±0.2* | 53.5±0.8* |
| 203 | 101.6±1.6 | 3.5±0.1 | 37.0±1.8 | 1.9±0.2 | 4.8±0.2* | 50.5±0.8 |
| 213 | 99.8±1.5 | 3.4±0.1 | 37.9±1.8 | 2.1±0.2 | 4.8±0.2* | 52.5±0.8* |
| 214 | 78.8±1.6* | 3.3±0.1 | 39.0±1.8* | 2.4±0.2* | 4.4±0.2 | 53.1±0.8* |
| 262 | 59.6±1.5* | 3.6±0.1 | 36.1±1.8 | 2.4±0.2* | 4.4±0.7 | 53.9±0.8* |

** - statistically significant difference from the Podolyanka standard at $P_{0.05}$*

Thus, it can be stated that the increase in yield can be both due to changes in the mechanism of yield capacity formation as compared to the previous form, and to the enhancement of the trait being the key one for the original form. It is impossible to identify more precisely the priority here, so obviously, large-scale studies are necessary in terms of the amount of material received at this point, so a factor analysis was performed (Table 5) in order to find out the most important prerequisite for increasing yield capacity: either variability due to the effect of gamma irradiation of individual elements of the yield structure or the perfection of the original genotypes (this is also important in view of the conclusion about the viability of certain forms as an original material).

As a result of factor analysis, it was established that the genotype conditioned a priority in the formation of such traits as productive tillering capacity and number of grains per main spike, that is, it was not possible to provide a significant level of such traits variability through the use of the mutagen. Variability due to the stem height (which affected the same coefficient of economic use – the ratio of the economic and vegetable parts) was conditioned by gamma irradiation only.

This suggests that it is the height, grain weight per spike and plant, and TKW that can be improved with gamma irradiation relatively easily, while other indicators are much harder to enhance. It also indicates the prospect of using more advanced local forms.

Table 5. Factor analysis findings (varimax raw)

| Parameter | Genotype | Gamma irradiation |
|---|---|---|
| Height of plants | 0.218111 | **0.544179** |
| Productive tillering capacity | **0.532458** | 0.176666 |
| Number of grains per main spike | **0.516141** | 0.075987 |
| Grain weight per main spike | **0.471919** | **0.117111** |
| Grain weight per plant | **0.521670** | **0.683080** |
| Thousand kernel weight | **0.492827** | **0.519850** |
| Total variance | 2.753126 | 2.116873 |
| Proportion of total variance | 2.535015 | 1.86422 |

*Note: The numbers in bold are statistically significant at $P_{0.05}$*

As mentioned above, increasing productivity alone is not a necessary prerequisite for the creation of a satisfactory crops agrocenosis from the standpoint of today's needs (Jaradat, 2018; Lykhovyd, 2021). The second necessary component is the technological qualities of the grain, which are due to such hereditary features as the protein content in the grain, the content of gluten, availability of glutenins and gliadins and their complex in relative content (Khalili *et al,* 2018). The viable forms are those with a protein content of 14% and higher, with a higher content of high-molecular weight glutenins, and with no increase in the low-molecular weight component (Nutall *et al,* 2017).

The results of the study by quality parameters for all high-productivity strains are shown in Table 6. According to the coefficient of the trait variation, the protein content and the total gluten content were referred to low-variable – that is, it is quite difficult to achieve significant changes for them, other traits were medium-variable and more favourable to the induction of new values for these parameters.

Table 6. Technological properties of grain

| Variety | Protein, % | Gluten, % | Glutenins | | | Gliadins |
|---|---|---|---|---|---|---|
| | | | HMW | LMW | Total | |
| Podolyanka | 13.99 | 25.59 | 0.16003 | 0.46485 | 0.62488 | 0.4598 |
| 26 | 13.55 | 23.99 | 0.20443* | 0.48435* | 0.68878 | 0.3565 |
| 45 | 12.88 | 22,23 | 0.21245* | 0.49453* | 0.70698 | 0.3453 |
| 123 | 14.21* | 27.15* | 0.24353* | 0.45467 | 0.6982 | 0.4325 |
| 152 | 13.95 | 25.66 | 0.21356* | 0.45465 | 0.66821 | 0.4231 |
| 178 | 13.57 | 24.54 | 0.20435 | 0.47100 | 0.67535 | 0.4324 |
| 179 | 14.27* | 27.17* | 0.21231* | 0.44454 | 0.65685 | 0.4657 |
| 181 | 14.14* | 26.98* | 0.21523* | 0.50333* | 0.71856 | 0.4456 |
| 203 | 13.13 | 23.11 | 0.19022* | 0.51760* | 0.70782 | 0.4200 |
| 213 | 13.92 | 24.99 | 0.18453 | 0.54300* | 0.72753 | 0.5048* |
| 214 | 13.55 | 24.18 | 0.18453 | 0.53999* | 0.72452 | 0.4448 |
| 262 | 14.32* | 27.62* | 0.20444* | 0.53545* | 0.73989 | 0.4948* |
| Average | 13.79 | 25.24 | 0.20247* | 0.49233* | 0.69480 | 0.4354 |
| $C_v$, % | 3.3 | 7.2 | 10.3 | 7.2 | 4.8 | 10.9 |

** statistically significant difference from the Podolyanka standard at $P_{0.05}$*

In terms of protein content, the standard was significantly dominated by such lines as 123, 179, 181, and 262. They were more advanced in terms of gluten content, which correlates with the protein content by a factor of 0.91. Lines 152 and 213 were as good as the standard forms. Other lines turned to be far worse. Unlike previous studies (Nazarenko and Izhboldin, 2017; Nazarenko *et al,* 2019a), the significance of a beneficial mutation process for such traits as semi-dwarfism (for individual genotypes) and stunting (Nazarenko *et al*, 2019b) has been shown, that is, it has been proved that the mutation is a reliable and permanent source for the local genetic resources (Hongjie *et al*, 2019) related to such traits, and that obtaining high-intensity stunting strains with a long grained spike (Keser *et al*, 2022) of early ripeness (Klčová *et al*, 2019; Kirova *et al,* 2021) and intense wax accumulation (Cann *et al*, 2022) (to eliminate the negative effects of drought) based on local material is quite possible and regular (Kirova *et al*, 2021).

The regularity of the beneficial mutational process has been described (Nazarenko and Bezus, 2018; Li *et al,* 2019), which allows to make the process of using this type of variability in order to obtain new material with the required potential more manageable, reliable and predictive (Nazarenko *et al*, 2021).

Based on the obtained material, it can be concluded that it is advisable to use mainly moderate doses of 100 – 150 Gy for the local material (Bondarenko and Nazarenko, 2020), and in some cases – a dose of 200 Gy (Nazarenko *et al*, 2019b).

For Steppe varieties, the combination of climatic factors and critical stages of development has become more favourable for the intensive (Western European) ecotype and seemingly allows less focus on local varietal resources. The studies show the key parameters of the existing mechanism of crop formation and the possibility of combining high yield capacity with quality grain based on local material due to the effect of gamma rays.

It should be recognized that it is possible and desirable to improve the local varieties for regional agriculture. Moreover, it should be noted that the obtained local varieties are as good as Western European varieties in terms of yield and quality. This cannot be considered as a positive trend, and the local breeding of new varieties of crops requires a significant increase in efforts. The key parameters for the formation of the yield capacity of local varieties are sufficiently flexible and variable for this purpose, and the quality has been sufficiently formed, although it is less mutable than the productivity traits.

## CONCLUSIONS

Local genetic material is a quite favourable base for the creation of high-yielding and high-quality material. While combined with the relevant factor that induces genetic variability at a sufficiently high level, viable strains can be obtained with quite satisfactory results. It should be taken into account that the key productivity traits are easier to change than the technological properties of grain, so it is still advisable to pay particular attention to this aspect when assessing the original material. Classical factors for genetic improvement due to the mutational process remain effective in creating high-yielding and high-quality material. Further research will focus on key parameters such as drought resistance, photosynthetic activity, peculiarities of the use and accumulation of nutrients for the studied varieties to confirm the parameters that provide the identified advantage in terms of grain yielding capacity and quality indicators. It is also planned to study new factors that induce mutational changes based on local and international germplasm.

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