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## 1) The frequency of chlorophyll mutations in soybeans.

The first mutations of soybeans in the USSR were received by Leschenko A. in the 30's. In the late 50's, through direct selection of mutations, the first variety called 'Universal 1' was received in the USSR. The second strain--'Wonder of Georgia'--was received through crossing of induced mutants of soybeans.

Short season, high productive as well as resistant to cold and heat mutants were induced by many scientists. Application of mutagen factors for improving protein and oil content as well as a gap in negative correlations existing among economic traits is proved to be perspective.

This article gives the data on genetic activity of a number of chemicals and gamma rays in induction of chlorophyll mutations of soybeans.

Water solutions of the following mutagen factors were used in research: nitrosoethyl urea (NEU), nitrosomethyl urea (NMU), ethylenimine (EI), ethylenoxide (EO), nitrosodimethyl urea (NDMU) and dimethylsulphate (DMS). For induction of mutations, various gamma ray doses were used.

The research showed that soybeans have a wide spectrum of chlorophyll mutations that are revealed during the entire period of vegetation. The greatest number of such mutations were found within the period of plants' initial growth. The total frequency of chlorophyll alterations in investigated varieties that depends on the type of mutagen used is given in Table 1.

Such mutagens as NMU, NEU, EI and gamma rays induced high frequencies of alterations of that kind. Fewer mutations were given by EO, NDMU and DMS. In general, NMU induced the highest number of mutations with all strains. As to genetic activity, the investigated mutagen factors could be given in the following succession: NMU > NEU > EI > gamma-rays > EO > DMS > NDMU. The frequency of mutations given by one mutagen is not the same for different varieties (Table 2). The most mutatable were varieties 'VNEEMK 9186' and 'Lanka'. 'Kirovogradskaya 4' and 'Peremoga' had average mutatability. 'Hybrid 89-10' had the lowest frequency of mutations. The mutagens that induced the higher frequency of mutations gave, as a rule, the wider spectrum (Table 3). Such mutagens as NEU, NMU, EI and gamma-rays in most cases had induced 2-3 types of chlorophyll mutations, while such low active mutagens as EO, NDMU and DMS gave only 1-2 types. Strain Peremoga, in comparison with other strains, had a wider range of mutation of such kind. In the second generation of varieties that were treated by chemical mutagens and gamma-rays, about 1,000 changed plants were singled out. Their selection significance and heredity are being studied at present. Among them there are strains with shortened growing season, high production, semi-dwarf, as well as mutants with changed content of protein and oil.

Table 1

Efficiency of chemical mutagens and gamma rays in induction of chlorophyll mutations dependable on strain's type genus

| Type of mutagen | Lanka | | Hybrid 89-10 | | Kirovograd- |
|---|---|---|---|---|---|
| | Investigated families $M_2$ | Frequency of mutations | Investigated families $M_2$ | Frequency of mutations | Investigated families $M_2$ |
| Control | 154 | 0 | 95 | 1.05 ± 1.05 | 119 |
| Gamma rays | 367 | 3.27 ± 0.93 | 314 | 3.82 ± 1.08 | 303 |
| NEU | 149 | 8.72 ± 2.31 | 139 | 7.91 ± 2.29 | 295 |
| NMU | 230 | 10.87 ± 2.05 | 240 | 3.75 ± 1.26 | 380 |
| EI | 289 | 5.19 ± 1.30 | 259 | 3.47 ± 1.14 | 204 |
| EO | 372 | 1.07 ± 0.53 | 254 | 1.97 ± 0.87 | 339 |
| NDMU | 168 | 0.60 ± 0.60 | 291 | 2.74 ± 0.58 | 250 |
| DMS | 166 | 4.82 ± 1.66 | 223 | 0.90 ± 0.63 | 231 |

Table 1 (cont'd)

| skaya 4 | VNEEMK 9186 | | Peremoga | |
|---|---|---|---|---|
| Frequency of mutations | Investigated families $M_2$ | Frequency of mutations | Investigated families $M_2$ | Frequency of mutations |
| 0 | 104 | 0 | 122 | 0.81 ± 0.71 |
| 3.30 ± 1.03 | 275 | 3.64 ± 1.13 | 373 | 4.29 ± 1.05 |
| 5.42 ± 1.32 | 206 | 10.68 ± 1.32 | 241 | 7.05 ± 1.65 |
| 11.05 ± 1.66 | 287 | 11.15 ± 1.86 | 302 | 9.93 ± 1.72 |
| 5.39 ± 1.58 | 258 | 10.85 ± 1.94 | 185 | 8.11 ± 2.01 |
| 1.77 ± 0.72 | 270 | 1.11 ± 0.64 | 364 | 3.02 ± 0.80 |
| 0.80 ± 0.56 | 247 | 0.40 ± 0.40 | 359 | 1.67 ± 0.68 |
| 0.43 ± 0.43 | 189 | 0 | 227 | 1.76 ± 0.87 |

Table 2

The frequency of chlorophyll mutations depending on strain's type genus

| Name of strain | Investigated families $M_2$ | Families singled out with mutations pcs | Frequency of mutations |
|---|---|---|---|
| Lanka | 1895 | 90 | 4.75 ± 0.49 |
| Hybrid 89-10 | 1815 | 54 | 2.97 ± 0.40 |
| Kirovogradskaya 4 | 2121 | 88 | 4.15 ± 0.43 |
| VNEEMK 9186 | 1836 | 95 | 5.17 ± 0.52 |
| Peremoga | 2173 | 89 | 4.09 ± 0.42 |

Table 3

Number of types of chlorophyll mutations induced with chemical mutagens and gamma rays

| Mutagen influence | Number of types of chlorophyll mutations | | | | |
|---|---|---|---|---|---|
| | Lanka | Hybrid 89-10 | Kirovogradskaya 4 | VNEEMK 9186 | Peremoga |
| Control | 0 | 1 | 0 | 0 | 0 |
| Gamma rays 2.5 | 3 | 2 | 2 | 2 | 2 |
| 5.0 | 1 | 2 | 2 | 3 | 4 |
| 7.5 | 2 | 3 | 4 | 2 | 3 |
| NEU 0.0125 | 2 | 3 | 3 | 4 | 1 |
| 0.025 | 2 | 4 | 2 | 1 | - |
| 0.05 | - | - | 1 | - | 4 |
| NMU 0.00625 | 3 | 1 | 4 | 2 | 3 |
| 0.0125 | 2 | 2 | 2 | 2 | 4 |
| 0.025 | 2 | 2 | 3 | 2 | 3 |
| EI 0.01 | 2 | 1 | 3 | 2 | 5 |
| 0.02 | 2 | 2 | 3 | 2 | 5 |
| 0.03 | 2 | 2 | - | 2 | - |
| EO 0.05 | 1 | 2 | 3 | - | 3 |
| 0.10 | 1 | 1 | 1 | 1 | 3 |
| 0.20 | 1 | 1 | 1 | 2 | 1 |
| NDMU 0.00625 | - | 1 | - | 0 | 2 |
| 0.0125 | 0 | 0 | 1 | 1 | 1 |
| 0.025 | 1 | 2 | 1 | 0 | 1 |
| DMS 0.01 | 2 | 0 | 0 | 0 | 1 |
| 0.02 | 2 | 1 | 1 | 0 | 2 |

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2) Morphological mutations of soybeans induced with chemical mutagens and gamma rays

The method of experimental mutagenesis is effective in investigating the hereditary alterations of plants with their further use in selection. Year by year the research in this field grows wider, covering new research institutions and crops.

The purpose of this article was to investigate the efficiency of a number of chemical mutagens and gamma rays in induction of morphological mutations in soybeans with their further use in selection of this crop.

The mutagen factors used gradually increased the frequency of visible morphological mutations. The frequency of mutations, in most cases, depended on the type of mutagen used, on its dose and variety (Table 1). The most effective among the mutagen factors turned out to be nitrosomethyl urea (NMU), nitrosoethyl urea (NEU) and gamma rays (Table 2). They induced 9.19-10.42% of visible mutations. Ethylenimine (El) took the intermediate position. Ethylenoxide (EN), nitrosodimethyl urea (NDMU) and dimethylsulfate (DMS) had practically the same activity, having induced 4.26-4.63% of morphological mutations. The similar position the aforementioned mutagens had in frequency of chlorophyll mutations excepting gamma rays. In induction of morphological mutations, gamma rays appeared to be 3 times more effective than in induction of chlorophyll mutations. Genetic activity of this mutagen was not inferior to NEU and NMU but was higher in comparison with the other chemical mutagens. It shows that gamma rays are a highly active mutagen for soybeans and they should be used more widely in experimental mutagenesis research of this crop.

It was registered that the frequency of mutations had a rather complex dependence on the dose of mutagen (Table 1); e.g., NMU induced the highest output of mutations with 'Lanka' and 'VNEEMK 9186' at average dose, with 'Hybrid 89-10' at initial dose and with 'Kirovogradskaya 4' and 'Peremoga' at the definitive dose. Peremoga and Kirovogradskaya 4 gave high mutability; Lanka and VNEEMK 9186, average; Hybrid 89-10, low (Table 3). Approximately the same level was produced in chlorophyll mutations, excepting VNEEMK 9186. This variety took the first place as to the frequency of chlorophyll abnormalities but as to the number of morphological mutations it was less mutatable. It is necessary to take into consideration that some mutagens can show high genetic activity only with definite genotypes; e.g., gamma rays induced the highest percentage of mutations with Hybrid 89-10, VNEEMK 9186 and Peremoga, at the same time they showed low efficiency with Lanka and Kirovogradskaya 4. It means that it is necessary to use several genotypes and mutagens for induction of a considerable number of hereditary changes. The used mutagen factors induced, in general, short season, long season, resistance to lodging, high production, tall, semidwarf, dwarf mutants with changed coloring of pubescence of stalk and pods, with changed number of pods on the plant. It is very important that short season mutants appeared rather often, because at present the problem of combination of short season and high productivity is one of the main problems in soybeans breeding in the USSR. That is why the use of induced mutations can bring considerable help in solving this problem. It was mentioned before that mutagens and varieties had a very similar succession according to their induction of morphological and chlorophyll mutations. However a more detailed analysis showed that this dependence has a complex character. Among the investigated varieties, for all mutagen treatments, only Kirovogradskaya 4 registered the high positive dependence between

Table 1

Frequency of morphological mutations in different varieties of soybeans

| Mutagen | Lanka | | Hybrid 89-10 | | Kirovograd- |
|---|---|---|---|---|---|
| | Investigated families | Frequency of mutations | Investigated families | Frequency of mutations | Investigated families |
| Control | 154 | 0.65 ± 0.65 | 95 | 1.06 ± 1.05 | 119 |
| Gamma rays | | | | | |
| 2.5 | 119 | 5.88 ± 2.16 | 132 | 7.58 ± 2.31 | 99 |
| 5.0 | 114 | 2.63 ± 1.50 | 97 | 9.28 ± 2.96 | 119 |
| 7.5 | 134 | 8.21 ± 2.38 | 85 | 3.53 ± 2.01 | 85 |
| NEU | | | | | |
| 0.0125 | 79 | 7.59 ± 3.00 | 72 | 4.17 ± 2.37 | 115 |
| 0.025 | 70 | 18.57 ± 4.68 | 67 | 5.97 ± 2.20 | 117 |
| 0.05 | - | - | - | - | 63 |
| NMU | | | | | |
| 0.00625 | 94 | 7.45 ± 2.72 | 93 | 4.30 ± 2.11 | 147 |
| 0.0125 | 68 | 17.65 ± 4.66 | 79 | 2.53 ± 1.78 | 155 |
| 0.025 | 68 | 8.82 ± 3.46 | 68 | 2.94 ± 2.06 | 78 |
| EI | | | | | |
| 0.01 | 99 | 6.06 ± 2.41 | 102 | 3.92 ± 1.93 | 93 |
| 0.02 | 90 | 5.56 ± 2.43 | 70 | 8.57 ± 3.37 | 111 |
| 0.03 | 100 | 4.00 ± 1.97 | 87 | 0 | - |
| EO | | | | | |
| 0.05 | 157 | 5.73 ± 1.86 | 72 | 0 | 120 |
| 0.10 | 118 | 4.24 ± 1.86 | 90 | 1.11 ± 1.11 | 120 |
| 0.20 | 97 | 6.18 ± 2.46 | 92 | 1.09 ± 1.09 | 99 |
| NDMU | | | | | |
| 0.00625 | - | - | 85 | 3.53 ± 2.01 | - |
| 0.0125 | 84 | 3.57 ± 2.04 | 74 | 4.05 ± 2.31 | 123 |
| 0.025 | 84 | 8.33 ± 3.03 | 132 | 1.52 ± 1.07 | 127 |
| DMS | | | | | |
| 0.01 | 73 | 4.11 ± 2.34 | - | - | 123 |
| 0.02 | 93 | 0 | 112 | 1.78 ± 1.26 | 108 |
| 0.04 | - | - | 93 | 0 | 94 |

Table 1 (cont'd)

| skaya 4 | VNEEMK 9186 | | Peremoga | |
|---|---|---|---|---|
| Frequency of mutations | Investigated families | Frequency of mutations | Investigated families | Frequency of mutations |
| 0.84 ± 0.84 | 104 | 0.96 ± 0.96 | 122 | 4.09 ± 1.80 |
| 5.05 ± 2.21 | 88 | 6.81 ± 2.70 | 174 | 20.69 ± 3.03 |
| 4.20 ± 1.85 | 87 | 14.94 ± 3.84 | 114 | 14.04 ± 3.27 |
| 4.70 ± 2.31 | 100 | 11.00 ± 3.14 | 85 | 16.47 ± 4.05 |
| 13.91 ± 3.24 | 130 | 5.61 ± 2.03 | 153 | 13.07 ± 2.73 |
| 10.26 ± 2.82 | 76 | 7.89 ± 3.11 | - | - |
| 7.94 ± 3.43 | - | - | 88 | 5.68 ± 2.48 |
| 14.28 ± 2.90 | 99 | 7.07 ± 2.59 | 136 | 7.35 ± 2.24 |
| 18.71 ± 3.14 | 122 | 11.47 ± 2.90 | 84 | 7.14 ± 2.83 |
| 24.36 ± 4.89 | 66 | 4.54 ± 2.58 | 82 | 9.76 ± 3.29 |
| 10.75 ± 3.23 | 96 | 5.20 ± 2.28 | 93 | 10.75 ± 3.23 |
| 8.11 ± 2.60 | 102 | 3.92 ± 1.93 | 92 | 16.30 ± 3.87 |
| -2 | 60 | 3.33 ± 2.34 | - | - |
| 5.83 ± 2.15 | - | - | 150 | 10.67 ± 2.53 |
| 5.00 ± 1.20 | 139 | 4.31 ± 1.73 | 94 | 6.38 ± 2.53 |
| 2.02 ± 1.42 | 131 | 2.29 ± 1.31 | 120 | 5.00 ± 2.00 |
| - | 78 | 1.43 ± 1.35 | 128 | 7.03 ± 2.27 |
| 1.63 ± 1.15 | 78 | 5.13 ± 2.51 | 136 | 3.68 ± 1.62 |
| 3.94 ± 1.73 | 91 | 5.49 ± 2.40 | 95 | 8.42 ± 2.86 |
| 4.88 ± 1.94 | 101 | 0.99 ± 0.99 | 108 | 6.48 ± 2.38 |
| 4.63 ± 2.03 | 88 | 10.23 ± 3.25 | 119 | 7.56 ± 2.43 |
| 5.32 ± 2.33 | - | - | 94 | 6.38 ± 2.53 |

the frequency of chlorophyll and morphological mutations (Table 4). The selection value of received mutant strains is being investigated at present.

Table 2

Influence of type of mutagen on the frequency of morphological mutations in soybeans

| Mutagen factor | Number of families | Frequency of mutations, % |
|---|---|---|
| Gamma rays | 1632 | 9.19 ± 0.72 |
| NEU | 1030 | 9.32 ± 0.90 |
| NMU | 1439 | 10.42 ± 0.81 |
| EI | 1195 | 6.28 ± 0.70 |
| EO | 1599 | 4.63 ± 0.52 |
| NDMU | 1315 | 4.26 ± 0.56 |
| DMS | 1206 | 4.39 ± 0.59 |

Table 3

Frequency of morphological mutations in different varieties of soybeans

| Name of variety | Investigated families | Frequency of mutations, % |
|---|---|---|
| Lanka | 1741 | 7.47 ± 0.63 |
| Hybrid 89-10 | 1702 | 3.47 ± 0.44 |
| Kirovogradskaya 4 | 2096 | 8.25 ± 0.60 |
| VNEEMK 9186 | 1732 | 6.06 ± 0.57 |
| Peremoga | 2145 | 9.51 ± 0.63 |

Table 4

Coefficient of correlation between the frequency of morphological and chlorophyll mutations in soybeans depending on the type of variety

| Name of variety | Coefficient of correlation |
|---|---|
| Lanka | + 0.21 |
| Hybrid 89-10 | - 0.02 |
| Kirovogradskaya 4 | + 0.96 |
| VNEEMK 9186 | + 0.11 |
| Peremoga | - 0.17 |

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