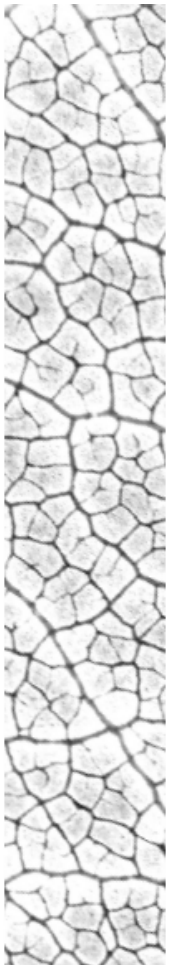

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# The algorithm selection of initial material corn by breeding for cold resistance and model of inbred line

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**Abstract**
The results of laboratory (cold-test method) and field assessment of corn inbred lines by cold-resistance breeding are presented. The scientific approach to selection of initial material for breeding on cold resistance are proposed on the basis of investigation results. The model cold-resistant inbred line was developedon the basis of the conducted evaluation in the laboratory and field conditions which is recommended for use in the breeding process.

**Keywords:** corn, inbred lines, cold resistance, cold-test, similarity and seed germination, identification, sowing term, inbred line model

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## THE ALGORITHM SELECTION OF INITIAL MATERIAL CORN BY BREEDING FOR COLD RESISTANCE AND MODEL OF INBRED LINE

Maize is a tropical culture with weak resistance to low temperatures (below 10 ° C).

It passed natural and artificial selection and adaptation to growth at low temperatures during the transition from the southern regions to the north. The hybrids are not completely cold resistance and, as a rule, they form low yields when cultivated in the northern regions (Rodriguez et al. 2008). The most cold-resistant populations have favorable alleles usable for improving cold resistance, at the same time.

The yield of corn hybrids is 14-16 tons per hectare today, even in the northern forest-steppe zone. It is much lower, primarily due to unstable weather conditions in the spring, in the area of Polissya.

There is always a risk of lowering temperatures to 0 ° C and below after sowing, which poses a risk for the growth of heat-loving hybrids of maize, especially on soaked soils, which leads to significant loss of crop in Polissia (Riva-Roveda and Perilleux 2015). The low temperature is one of the most important deterrent factors in the cultivation of maize in northern latitudes at the beginning of vegetation (Ali et al. 2015, Guan et al. 2009).

The sowing of cold-resistant hybrids at an average soil temperature at the depth of seeding + 6-7 ° C is successful for growing corn and obtaining guaranteed stairs in this area. The "sowing-ladder" period is longer in the early term of sowing for non-cold resistant hybrids. This leads to a decrease field similarity and energy of initial growth as a result of the violation of physiological processes during germination and increasing the affection of seeds by mould diseases (Gudz and Lavrinenko 1997).

The low positive temperatures differently action on plants, it is manifesting in decries the germination energy and viability of the seeds (Allesi and Power 1971, Andrew 1972, DeVries et al. 2007).

The cold stress affects photosynthetic activity, the osmotic ability of the plant and can cause cell damage (Matthews and Khajeh-Hosseini 2011, Riva-Roveda and Perilleux 2015). This impact is expressed in a decrease productivity by 10-15%, a change in the chemical composition and quality of the resulting products (Lahanov 1988). It is necessary to create hybrids with increased resistance to reduce the negative effects of cold on corn plants. It is necessary to involve the initial material inbred lines, which not only possess high cold resistance, but also pass this trait to the descendants. The selection the right method for determining the cold

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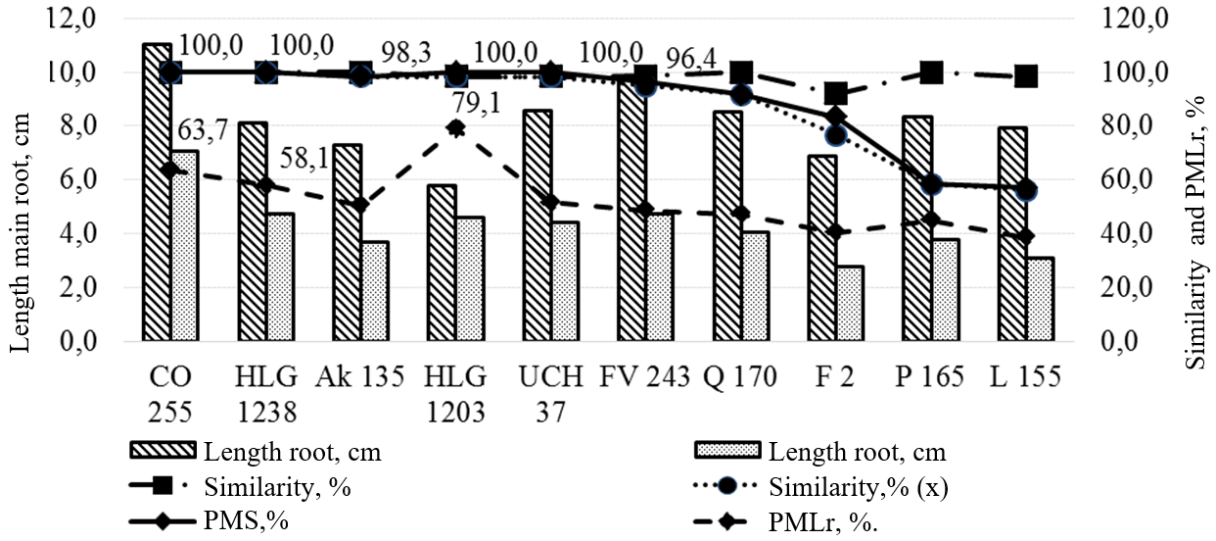


**Fig. 1.** Description best inbreed lines by results *cold test*, 2009 year

resistance of corn first to the parent forms, and then the hybrids created with their participation is also important.

The aim of the research is to assess the breeding value of corn inbred lines by cold resistance to main economic and value indicators and determining the optimal combination of parent components for the creation of high-yielding cold-resistant hybrids.

The research tasks included:

- identify inbred lines in laboratory and field conditions for cold resistance and basic economic-valuable signs;
- classify the initial material according to the degree of cold resistance;
- make a forecast selection of initial material by indicators of “cold resistance” and “yield” on the basis of laboratory tests, with subsequent inclusion to the crossing for creating cold-resistant hybrids;
- develop and recommend breeding practices for a cold-resistant inbred line model on the basis of laboratory and field research.

Object of research: the breeding value of corn inbred lines by signs “cold resistance” and “yield”.

Subject of research: maize inbred lines different genetic origin.

## MATERIALS AND METHODS

### Materials of Research

Materials for research were 150 samples initial material corn of domestic and foreign breeding: from the collection of the N.I. All-Russian Research Institute of Plant Industry (VIR) (St. Petersburg) - 108 samples, National Center for Plant Genetic Resources of Ukraine (Kharkiv) - 34 samples; department genetic, breding and seed production of NULES of Ukraine - 3 samples; NSC “Institute of Agriculture of the National Academy of Sciences of Ukraine” - 2 samples and LLC “Rasava” - 3 samples.

### Methods of Laboratory and Field Research

The most informative method is proposed by Kyyashko (cold test), which allows short-term identification of cold-resistant genotypes according to the results of evaluation of existing techniques. The laboratory determination of cold resistance carried out according to the method of Kyyashko (1992). It involved the germinating of 50 seeds of corn in a triple repetition between the filter paper for 20 days at a temperature of + 10 °C. The test specimens were transferred to a thermostat with a temperature of + 25 °C. for three days for final calculations after that.

Comparison of similarity indicators was performed with control germination under optimal conditions at + 25 °C for 7 days (DSTU 4138-2002).

Field researches were conducted in accordance with “Methodological recommendations for field and laboratory investigation of corn genetic resources” (2003). The investigation of collection samples of corn was carried out in four-time repeat with the renamed placement of sites. The accounting area of sites were for inbred lines - 4.9 $m^2$, for hybrids - 9.8 $m^2$.

Observations and accounting were performed according to the “Descriptor reference book for the Zea mays species” (2009) and “Field Experiments Methods” by Dospechov (1985).

The evaluation of samples for grain yield was carried out during the weighing method. Moisture content of the grains was determined by moisture meter Wile 55.

The seed was carried out at different soil temperatures at the depth of seeding (5-6 cm) in the field for the purpose of determining the cold resistance. The first period of sowing was carried out at soil temperature - 6 ... 6.5 ° C, the second - 8 ... 8.5 ° C, and the third - 10 ... 10.5 ° C. The control served the third term of sowing under optimal conditions.

**Table 1.** Distribution investigated samples of maize to groups for cold resistance

| Potential similarity, % (20 days germination at +10°C) \ Final similarity, % (3 days growing at +25°C) | H ≥ 95<br>L ≥ 95 | H ≥ 80-94<br>L ≥ 70-94 | H < 80<br>L < 69 |
|---|---|---|---|
| 95-100 | 24 (I) | 1 (III) | 0 (VI) |
| 70-94 | 12 (II) | 17 (V) | 0 (VI) |
| < 69 | 6 (IV) | 23 (V) | 8 (VI) |

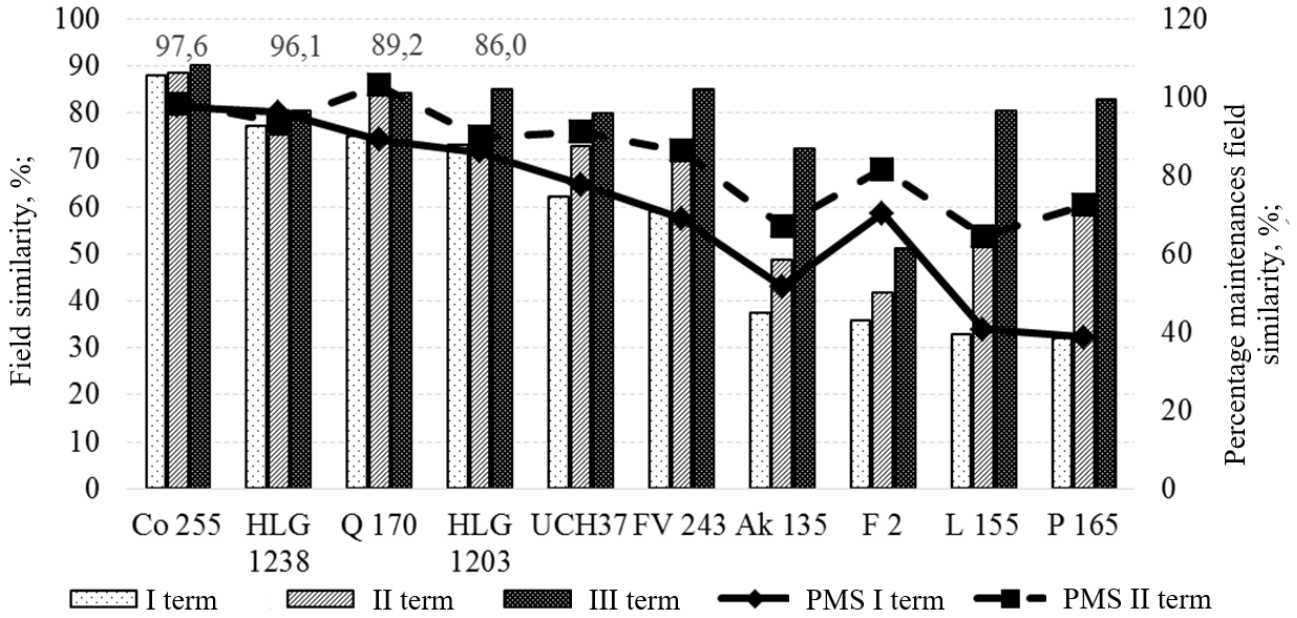


**Fig. 2.** Field similarity and PMS best inbreed lines corn, 2010-2011 years

## RESULTS AND DISCUSSION

The definition of cold-resistant specimens is primarily based on the determination of similarity under cold conditions of germination. A modified classification is proposed for the determination and selection of cold-resistant samples based on the results of the cold test that allows the distribution of samples to groups and to distinguish cold-resistant among them (**Table 1**). The distribution of inbred lines was carried out, according to which the 24th line was entered into the first group, to the second - 12th, to the III - 1, to the IV - 6, to the V - 40 and to the VI - 8th according to the results of the cold test.

The inbred lines have the best reparative ability: HLG 1203, HLG 1238, Co 255, UCH 37 and FV 243 it was found in the research. The highest similarity was observed in cold germination and its preserves relative to control germination (variation within 96.4-100.0%) in these lines

The lines Co 255, FV 243, HLG 1203, HLG 1238 formed the longest main root (4.6-7.0 cm). The highest percentage of preservation length of the root (58.1-79.1%) was observed for lines HLG 1203, Co 255 and HLG 1238.

Estimation of cold resistance of corn inbred lines in field conditions. Field similarity of inbred lines ranged from 51.1% to 90.0% for the optimal sowing period averaged over two years (**Fig. 2**). It decreased and varied within the limits - 32.1-87.8% for most lines in the first early sowing period. In the second period of sowing varied within 41.8-88.5%

The highest similarity was noted for lines: Co 255 - 87.8-88.5%, HLG 1203 - 73.0-76.3%, HLG 1238 - 77.2-75.3%, and Q 170 - 75.0-86.6% in two years at early terms of sowing. They also had the highest percentages of preservation of similarity in comparison with control (the third term of sowing) - 86.0-103.0%.

Phenological phases of development and duration of the vegetation period of inbred lines, depending on the term of sowing. The early seeding practically did not affect the length of the vegetation period, which varied within 101-110 days for the first term, 99-110 for the second and 99-113 for the third.

The results of biennial investigation indicate that with the shift of the sowing term to the earlier, the time of flowering is shifted left by panicle rool and corn cob.

The plant height varied within 132.2-243.6 cm for the first sowing period, for the second it was 130.3-246.3 cm and the third one was 145.4-234.0 cm. The earlier term of sowing was mostly contributed to the formation of higher plants. The height of the lines FV 243, Q 170 did not actually depend on the sowing date, and in the line HLG 1203, the highest plants were formed in the third sowing period - 146.4 cm although.

**Table 2.** Productivity inbreed lines of corn by optimal (+10…10,5ºC) and earlies (+6…6,5 ºC; +8…8,5 ºC) sowing term (2010-2011 years.)

| Line name | Sowing term | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | 1 (+6…6,5°C) | | | 2 (+8…8,5°C) | | | 3 (+10…10,5°C) | | |
| | 2010 | 2011 | X | 2010 | 2011 | X | 2010 | 2011 | X |
| HLG 1203 | 2.1 | 3.0 | 2.6 | 2.8 | 2.8 | 2.8 | 2.9 | 2.8 | 2.9 |
| HLG 1238 | 2.9 | 3.0 | 2.9 | 2.8 | 3.0 | 2.9 | 2.7 | 3.1 | 2.9 |
| FV 243 | 3.5 | 3.9 | 3.7 | 3.1 | 4.1 | 3.6 | 2.6 | 3.6 | 3.1 |
| Q 170 | 2.2 | 3.3 | 2.8 | 2.0 | 4.3 | 3.1 | 2.7 | 3.9 | 3.3 |
| Co 255 | 3.0 | 3.9 | 3.4 | 2.7 | 4.6 | 3.7 | 3.5 | 4.1 | 3.8 |
| UCH 37 | 1.2 | 2.8 | 2.0 | 1.5 | 2.0 | 1.7 | 1.5 | 2.2 | 1.9 |
| Ak 135 | 1.9 | 1.9 | 1.9 | 1.7 | 1.9 | 1.8 | 2.7 | 2.4 | 2.5 |
| F 2 | 1.1 | 1.8 | 1.4 | 1.2 | 2.5 | 1.9 | 1.6 | 3.4 | 2.5 |
| P165 | 0.8 | 2.9 | 1.9 | 1.0 | 2.5 | 1.7 | 1.7 | 3.5 | 2.6 |
| L 155 | 0.5 | 1.7 | 1.1 | 0.5 | 2.3 | 1.4 | 0.8 | 3.8 | 2.3 |
| $HIP_{0.05}$ | 0.24 | 0.35 | | 0.21 | 0.34 | | 0.30 | 0.37 | |

The height of fastening productive corn cob in the first term of sowing varied within the limits - 34,8-80,3 cm, the second - 32,4- 80,1 cm and the third - 33,2-80,3 cm.

The highest average height of fastening productive corn cob was found for the lines Co 255, FV 243, P 165 and UCH 37 - 48.2-80.2 cm, indicating their greatest suitability for industrial harvesting.

The average number of rows in corn-cob all lines is - 14.0 ± 0.45 pieces for the first sowing term, for the second - 13.9±0.44 and the third - 14.1 ± 0.45 pieces.

The largest number of rows for all sowing periods the lines: Co 255 - 15.4 ± 0.33, HLG 1203 - 16.0 ± 0.59 and UCH 37 - 17.1 ± 0.31 formed. The number of grains in the row for the first term of sowing averaged for all lines was 28.4 ± 1.20 grains per row, for the second - 26.8 ± 1.56 and the third - 28.3 ± 1.44, in accordance. The lines FV 243 – 34.0 ± 2.07, Ak 135 – 31.1 ± 1.16 and HLG 1203 – 29.7 ± 1.72 formed the largest average number of grains in the row. The line was formed the highest average mass of 1000 grains during the first and third sowing term - 236.6 g and 233.2 g, in accordance.

### Crop Yield and Moisture Content of Corn Inbred Lines

It was found the genotypes for yields respond differently to the term of sowing by analysis of each inbred line. The FV 243 line, on average, the two years of the first sowing term formed the highest yield - 3.7 t / ha, compared with same yield for the three sowing terms - 2.8-2.9 t / ha and 1.7-2.0 t / ha, in accordance (**Table 2**).

The lines FV 243 - 3.7 t / ha, Co 255 - 3.4 t / ha and HLG 1238 - 2.9 t / ha formed the highest average yields for the first sowing term. For the second term of sowing the line: Co 255 - 3.7 t / ha, FV 243 - 3.6 t / ha and HLG 1238 - 2.9 t / ha. These lines have the highest potential cold resistance.

The average moisture content of grain for all lines during the years of the test was 18.2% for the first sowing term, the second - 17.1% and the third - 17.7%. The cold-resistant lines had a slightly higher grain moisture content at early sowing term, compared to the third. The line HLG 1203 for the first term of sowing has a low humidity – 18.8%, whereas for the third one – 16.6. The same trend is noted for lines HLG 1238, FV 243, UCH 37.

The breeder must create a model line that will send desired signs to descendant before designing a hybrid model.

The maximum number of desirable signs should be collected in the basis of a cold-resistant inbred line, which will inherit created hybrids in the future along with this. The characteristics of a cold-resistant inbred line, taking into account the main morphological features and resistance to biotic and abiotic factors is given **Table 3**.

The inbred line must own high cold resistance, having a well-developed plant with the height within the range of 151-200 cm. In this case, the height of fastening productivit6y corn-cob 71-100 cm is optimal for industrial harvesting during seeding.

It is desirable to have the erectoidal placement of leaves. The leaves must be medium width and with a dark color. There is a better insolation, increasing the effectiveness of photosynthesis, and the accumulation of dry matter in darker leaves, accordingly. The inbred lines should positively react to the thickening of the sowing, which in principle is explaining by the angle of the leaf blade 5-30 °.

The light getting a large area of the leaf blade and increases the efficiency of photosynthesis with this position.

The corn-cob should be 15-18 cm length, with 14-16 rows of grains and up to 35 grains per row. The type of grain is desirable semidentata type, as this type combines high grain density (high 1000 kernels weight) and fast humidity transfer. The hollow at the top of the grain contributes rapid humidity transfer.

The inbred line must possess a high tolerance to drought, resistance to stalk lodging and against pathogens in general. Primarily against diseases such as Head and Common smut, Fusariosis which cause the most damage to corn seedling in the northern regions of Ukraine.

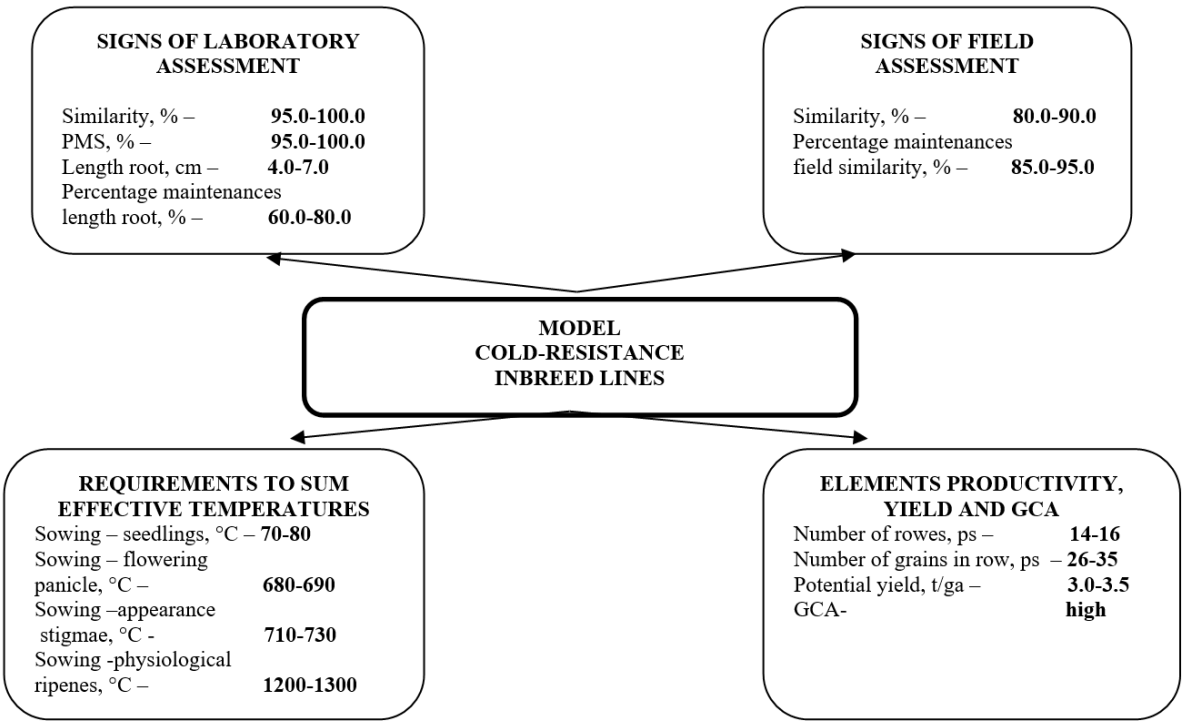


**Fig. 3.** Model cold-resistance inbreed lines of corn

**Table 3.** The characteristics of a cold-resistant inbred line, taking into account the main morphological features and resistance to biotic and abiotic factors

| № п/п | Sign | Degree of manifestation of the sign | annotation (by descriptor) |
|---|---|---|---|
| 1 | Vegetation period, days | 91-100 | mild-early |
| 2 | Simultaneity of seedling emergence, % | >75 (evenly) | high |
| 3 | Rate of initial growth (cm/days) | 6-9 | strong |
| 4 | Height of main stalk, cm | >151-200 | very high |
| 5 | Height of fastening of an upper product corn-cob, cm | 71-100 | high |
| 6 | Number of leaves on the main stalk, ps | 13-15 | |
| 7 | Leaf blade color | Dark-green | |
| 8 | Leaf blade | erectoidal | |
| 9 | Number of corn-cob on plant, ps. | 1 | very low |
| 10 | Pedicel length ear, cm | 5-10 | short |
| 11 | Corn-cob lenght, cm | 15-18 | long |
| 12 | Diameter of the middle part of a corn-cob, cm | 4,1-5,0 | thich |
| 13 | Deviation corn-cob from stalk, ° | 5 | intermediate |
| 14 | Type of grains | Semidentata Kulesh. | |
| 15 | Cob thinness, cm | 1,8-2,0 | thin |
| 16 | Grain yield, % | 81-85 | high |
| 17 | 1000 kernel weight, g | 251-300 | high |
| 18 | Drought resistance | 7-8 | high |
| 19 | Resistance to stalk lodging | high | |
| 20 | Resistance to Head smut | high | |
| 21 | Resistance to Common smut | high | |
| 22 | Grain humidity of havesting, % | 15-20 | medium |
| 23 | Potential yield, т/га | 3,0-3,5 | |

The yield of the inbred line should be in the range of 3.0-3.5 t/ha. The line should be characterized by high values of the GCA and the SCA on such signs as “yield” and “cold resistance”, which are the determining indicators for creation high-yielding cold-resistant hybrid.

It is difficult to predict how an economic-valuable sign will manifest itself in different combinations and conditions of cultivation by modeling hybrids. The most morphological and adaptive signs have a complicated inheritance nature that has a polygenic character. Therefore, the strategy of modern breeding is a deep investigation of these signs, which will allow the management of the processes of their inheritance.

## CONCLUSION

The cold-resistant genotypes identified based on the experimental research that can uses as sources of cold resistance in subsequent breeding prosses.

It is recommended to use a cold germination (cold test) method, which involves germinating seeds for 20 days at + 10 ° C, and treating for 3 days at + 25 ° C for corn under laboratory conditions as the main method for determining cold resistance:

1. The inbred line of corn for cold resistance and main economic-valuable indices are identified in the laboratory and field conditions: Co 255, HLG 1203, HLG 1238, UCH 37, Q 170, Ak 135, FV 243, which are characterized high laboratory similarity by cold germinating test – 91.7-100.0%, length of the main root 3.7-7.0 cm and the percentage of preservation of the length of the main root – 47.3-79.1%.

2. The inbred lines according to the economic-valuable signs and the degree of cold resistance are classified according to the modified method. Among the 91 investigated lines to the 1st group included - 24 lines, to II - 12, to III - 1, to IV - 6, to V - 40 and to VI - 8.

3. The high direct correlation between the length of the main root and the yield during the years of investigation + 0.79 ± 0.05, and between the laboratory similarity for the germination by the cold test method and the field similarity of the early sowing terms, which was on average: for the first sowing date - 0.73 ± 0.06 and the other - 0.56 ± 0.09 were defined.

4. It is recommended to use the laboratory method of determining the cold resistance cold test as an alternative to the field method. The model cold-resistant inbred line has been developed based on a comprehensive assessment of cold resistance in field and laboratory conditions. The main parameters are: laboratory similarity in the case of germination by cold test – 95.0-100.0%; field similarity in early sowing (+ 6-6.5 °C) – 80.0-90.0%; the sum of effective temperatures during the period of “sowing-sidling” - 75-80 ° C; yield – 3.0-3.5 t/ha and others.

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