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Study of frost resistance and grain yield of common winter wheat breeding lines

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Abstract: During the period 2019 - 2024, a study on the frost resistance and grain yield of 40 breeding lines and standard varieties of common winter wheat was conducted. The breeding lines were created through the method of intervarietal hybridization in IPGR-Sadovo, Bulgaria. Frost resistance was assessed by controlled freezing in a temperature-regulated chamber. As standards were used varieties Mironovska 808, Pobeda, Bezostaya 1, Rusalka, N 301 and San Pastore, which possess different level of the frost resistance. The average values were obtained based on plant survival rate after exposure to temperatures reaching to -18°C. The breeding lines ranking was determined using the calculated confidence interval for each standard based on the obtained data. The productivity was evaluated after experimental cultivated and harvested to four replications per growing period. The lines productivity was compared to the standard variety Sadovo 1 through computed ANOVA analysis. The highest frost resistance was found for the breeding lines MH 270/27, MH 268/1008 (Sashez), RU 32/2072,73,74 (Yailzla), MH 187/3 (Nadita), RU 77/878, RU 128/2900, RU 82/1476, RU 93/1895, RU 79/1373, MH 260/1175, BA 769, BA 861, BA 665, BA 535, BA 968 and BA 578 (Blan). Taking into account the expressed frost resistance and parameter grain yield, it could be concluded that the breeding lines MH 268/1008 (Sashez), RU 32/2072,73,74 (Yailzla), RU 76/1321, RU 33/3244, MH 260/1175, BA 769, BA 665, BA 535 and BA 578 (Blan) combine high frost resistance and productivity.

Keywords: common winter wheat; breeding lines; frost resistance; frost chamber; productivity

INTRODUCTION

Grown on more than 200 million hectares of land worldwide, wheat is now the most widely cultivated cereal in the world, as well as one of the most important crops for global food security (Shiferaw et al., 2013). The main purpose of any breeding program is the creation of varieties combining high productive potential and good quality under different environmental conditions. It is particularly important for the new varieties to possess enhanced stability and plasticity (Dimitrov et al., 2022; Tsenov et al., 2022; Uhr et al., 2023).

Winter wheat growing areas in the Northern hemisphere are regularly exposed to heavy frost. Due to the negative impact on yield, the identification of genetic factors controlling frost tolerance (FroT) and development of tools for breeding is of prime importance (Soleimani et al., 2022). Winter wheat plants simultaneously vernalize and increase freezing tolerance through acclimate to cold when grown at low positive temperatures. The effects of the interaction of temperature and photoperiod on vernalization response are complex (Sandve et al., 2011; Allard et al. 2012). Due to the cold acclimation phenomenon, winter cereals survive frost by regulating their metabo-

lism at low temperatures and protecting critical structures of cells against freezing temperatures (Vagujfalvi, et al., 2003; Armoniene et al., 2013).

In the region of Sadovo winters are comparatively milder, but in January and February the radiation temperature decreases abruptly for 2 - 3 days, getting as low as -15°C to -18°C with little or no snow cover. This makes possible the periodic exclusion on the less frost-resistant forms (Chipilski and Uhr, 2014). The breeding program of common winter wheat IPGR "K. Malkov" underlines a strategy, in which for evaluation of breeding materials are accepted methods of direct freezing (Rachovska et al., 2007; Tsenov et al., 2009; Chipilski and Uhr, 2014; Nikolova et al., 2021). By imitation of winter conditions and the regulation of low temperatures, it is possible to do a more accurate assessment of the breeding materials and varieties of common winter wheat when the natural environmental conditions do not allow this (Chipilski and Uhr, 2014).

The aim of the study is to select frost resistance and high productivity breeding lines of common winter wheat created in IPGR Sadovo.

MATERIAL AND METHODS

The study was conducted in IPGR "K. Malkov"- Sadovo, Bulgaria during the period 2019 - 2024. 41 lines and varieties of common winter wheat were studied for cold resistance among plants, selected by methods of intervarieties hybridization and experimental mutagenesis. Direct method of freezing plants in freezing chamber at -18°C for 24h is applied (Tsenov and Petrova, 1984; Boyadjieva and Stankova, 1990). Plants are grown and vernalized under autumn environmental conditions in special containers in two replications, each containing 25. The plants were placed in the chamber during their tillering stage. The days, chosen for freezing were in January, which coincides with the period of maximum cold tolerance of plants. After being removed from frost chamber, plants were recovered for a period of 30 days. The percentage of plants survival was calculated with the formula: $P = (n/N) \times 100 (\%)$,

where: P-% of plants survival; n-number of survived plants; N-total number of plants (13). Thus, not only the survival rate at low subzero temperatures is reported, but also their ability to restore. For comparison were used standards for cold tolerance accepted by EAVTA-Executive Agency for Variety Testing and Approbation in Bulgaria, as follows Mironovska 808, Pobeda, Bezostaya 1, № 301, Rusalka and San Pastore, arranged in order of their cold tolerance. The study included accepted for yield standard variety Sadovo 1. Based on the obtained data was calculated the confidence interval for each standard and breeding lines. The ANOVA analysis (Program Excel for Windows 10) was used to determine the significance of yield difference between genotypes.

RESULTS AND DISCUSSION

Meteorological conditions during autumn and winter for a period 2019 - 2024

The presented data of mean daily temperatures shows a distinct difference between the years of study and the 30-year period (Figure 1). For all six consecutive years, as well as for the four months of the period, there has been an increase in mean daily temperature. Interestingly, with very few exceptions, this increase has been consistently higher over the years. The figure shows additionally the highest monthly mean temperature values measured for each month in this six-year period, which are significantly higher compared to the 30-year period. It was also found that the greatest increases in temperatures were for the months of December and January, by 200% and 300%, respectively (Figure 1). Temperature conditions over the six-year period were the reason for faster growth and unhardening of plants in the pots during their placement in the cold chamber. This fact led to a lower average level of cold resistance and to the use of milder sub-zero temperatures for better selection differentiation.

Frost resistance

The results for cold resistance of the selected tolerant winter wheat breeding lines, which were

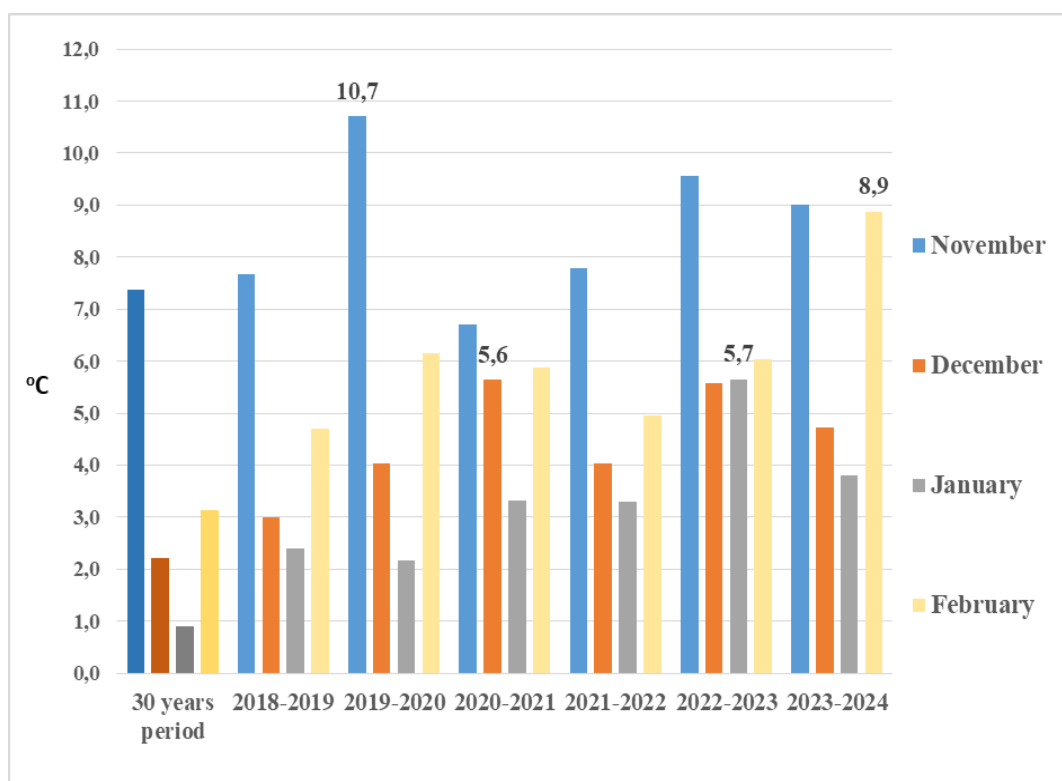


Figure 1. Mean daily temperature during autumn and winter for a period 1919 - 2024

investigated during six years period, are presented in Table 1. The selection of these breeding lines was a result of the expressed stability trend by this parameter. A lot of them belong to the excellent cold resistance standard varieties Mironovska 808 and Pobeda. These are breeding lines MH 270/27, MH 268/1008, RU 32/2072,73,74, MH 187/3, RU 77/878, RU 128/2900, RU 82/1476, RU 93/1895, RU 79/1373, MH 260/1175, BA 769, BA 861, BA 665 and BA 578. The nine breeding lines were classified with very good cold resistance Bezostaya 1. The insufficient ambient condition for hardening after vernalization leads to difficult expressing of the full survival rate -100%, despite applying higher sub-zero temperature. The calculated confidence interval indicated no significant difference between standards from St.1- Mironovska 808 to St.4-№ 301, and ranked breeding lines, respectively. Nevertheless, the presented ranking indirectly separated the most cold-resistant genotypes. The results were expected, showing that the most sensitive at low subzero temperature are Rusalka and San Pastore

varieties, characterized with low survival rate, respectively 45.0 % and 14.6 %. Their difference is significant at $p=0.05$ compared to the remaining four standards (Table 1). This fact is a proof for high cold resistance manifestation of the studied wheat breeding lines. Similar data for gradually decreasing resistance to low temperatures for the six standard varieties were obtained by other research (Petrova., 2002; Chipilski et al., 2012), which allows us to use them as a standard scale.

Productivity of the frost resistance breeding lines

The results concerning the grain yield obtained from evaluated breeding lines are presented in Table 3. Significant positive differences in parameter grain yield were calculated for the lines MH 268/1008, MH 270/50, MH 270/24, RU 32/2072,73,74, RU 33/3244, MH 260/1175, BA 769, BA 535 and BA 665, compared to standard Sadovo 1. From all selected frost resistance breeding lines in this study, eight lines have lower productivity compared to standard Sadovo 1.

Table 1. Frost resistance of common winter wheat during the period 2019 - 2024

Varieties and breeding lines	Average survivor of plant at -20°C /24 h (%)	Confidential interval	Classifying
St₁-Mironovska 808	94.6	100.0-86.6 ^{n.s.}	I
St₂-Pobeda	89.5	100.0-78.6 ^{n.s.}	II
St₃-Bezostaya 1	80.5	94.7-66.4 ^{n.s.}	III
St₄- № 301	67.9	84.6-51.2 ^{n.s.}	IV
St₅- Rusalka	45.0	62.8-27.2 *	V
St₆-San Pastore	14.6	27.2-2.0 *	VI
Sadovo 1	84.3	97.3-71.2	II
Avenue	82.8	96.3-69.3	III
MH 270/24	84.9	97.7-72.0	II
MH 270/28	81.7	95.5-67.9	III
MH 270/27	93.4	100.0-84.6	I
MH 270/50	85.4	98.0-72.8	II
MH 270/86	80.0	94.3-65.6	III
MH 268/1008	97.5	100.0-91.9	I
RU 32/2072,73,74	93.3	100.0-84.4	I
MH 187/3	92.6	100.0-83.2	I
RU 79/1419	74.5	90.1-58.9	III
RU 76/1321	71.4	83.5-55.2	III
RU 76/1332	85.2	97.9-72.4	II
RU 128/2900	96.6	100.0-90.0	I
RU 77/878	95.9	100.0-88.7	I
RU 82/1476	94.4	100.0-86.2	I
RU 79/1373	94.5	100.0-86.3	I
RU 91/1729	77.1	92.1-62.0	III
RU 93/1895	95.7	103.0-88.4	I
RU 33/3244	86.4	98.7-74.1	II
MH 260/1175	97.6	100.0-92.0	I
BA 574	88.4	99.9-77.0	II
BA 578	93.5	100.0-82.8	I
BA 805	88.3	99.8-76.8	II
BA 577	81.6	95.4-67.7	III
BA 803	91.1	100.0-80.9	II
BA 778	83.1	96.5-69.7	III
BA 782	83.0	96.4-69.6	III
BA 769	92.3	100.0-82.8	I
BA 535	84.3	97.3-71.2	II
BA 918	87.9	99.6-76.2	II
BA 968	84.7	97.5-71.8	II
BA 861	93.7	100.0-85.0	I
BA 665	92.2	100.0-82.6	I

* Significance deference at 5 % compared to standards Mironovska 808 and Pobeda; n.s.-no significance difference

During the six-year period, when the study has been carried out, the high productivity genotypes MH 268/1008, RU 32/2072,73,74, MH 187/3 and BA 578 are accepted for cultivars by EAVTA-Bulgarian Executive Agency for Variety Test-

Table 2. Productivity of common winter wheat during the period 2019 - 2024

Varieties and lines	Yield, kg/da	Compared to a standard	Significance difference
Sadovo 1 -St.	598.9	-	
MH 270/24	680.8	81.9	*
MH 270/28	631.4	32.5	n.s.
MH 270/27	608.1	9.3	n.s.
MH 270/50	661.0	62.1	*
MH 270/86	591.2	-7.7	n.s.
MH 268/1008	673.2	74.3	*
RU 32/2072,73,74	703.5	104.7	*
MH 187/3	649.1	50.2	n.s.
RU 79/1419	536.1	-62.8	n.s.
RU 76/1321	519.9	-79.0	*
RU 76/1332	540.2	-58.7	n.s.
RU 91/1748	604.6	5.7	n.s.
RU 128/2900	613.2	14.3	n.s.
RU 77/878	534.2	-64.7	n.s.
RU 82/1476	551.9	-47.0	n.s.
RU 79/1373	592.5	-6.4	n.s.
RU 91/1729	643.6	44.7	n.s.
RU 93/1895	610.8	11.9	n.s.
RU 33/3244	671.3	72.4	*
MH 260/1175	680.6	81.8	*
Sadovo 1-St.	647.3	-	n.s.
Avenue	685.3	38.0	n.s.
BA 574	660.6	13.3	n.s.
BA 578	685.7	38.4	n.s.
BA 805	664.5	17.2	n.s.
BA 577	628.0	-19.3	n.s.
BA 803	657.8	10.5	n.s.
BA 778	701.5	54.2	n.s.
BA 782	701.1	53.8	n.s.
BA 769	743.8	96.5	*
BA 535	713.2	66.0	*
BA 918	656.2	8.9	n.s.
BA 968	656.4	9.1	n.s.
BA 861	698.4	51.1	n.s.
BA 665	710.0	62.7	*

lsd 5.0%=61.2*

lsd 1.0%=81.3**

lsd 0.1%=105.5***

n.s.- no significance difference

ing and Approbation. A comparative study with these new varieties published by Vasileva et al., 2023 reported on their stability under different fertilizer levels and weather conditions, ear productivity, harvest index and postharvest biomass accumulation.

CONCLUSIONS

1. During the six years period, the highest frost resistance expressed the breeding lines MH 270/27, MH 268/1008 (Sashez), RU 32/2072,73,74 (Yailzla), MH 187/3 (Nadita), RU 77/878, RU 128/2900, RU 82/1476, RU 93/1895, RU 79/1373, MH 260/1175, BA 769, BA 861, BA 665, BA 535, BA 968 and BA 578 (Blan).

2. The breeding lines MH 268/1008 (Sashez), RU 32/2072,73,74 (Yailzla), RU 76/1321, RU 33/3244, MH 260/1175, BA 769, BA 665, BA 535 and BA 578 (Blan) combine high frost resistance and productivity.

3. The breeding lines created by IPGR-Sadovo are suitable for growing in regions with adverse environmental conditions during winter period.

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