UDK 633.1:581.1

ADAPTABILITY OF WINTER CEREALS AND THEIR VARIETIES TO ABIOTIC WINTER FFACTORS

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The studies have determined frost resistance and winter hardiness levels of current varieties of winter cereals, revealed their association with geographical origin of the varieties. The relations between winter cereals were defined by the value of variety winter hardiness, and the levels of their kinship were established on this basis.

The necessity of screening of frost resistance of winter varieties under controlled conditions, which allows restricting the introduction of varieties with insufficient frost resistance in agricultural production, prevents considerable financial loss of enterprises due to winter-killing of crops, and increases the production efficiency of winter cereals, was proved.

It is recommended to involve winter rye varieties and hybrids in the production and expand the area under this culture, which will provide secured overwintering of winter crops even in weather unfavorable years and will help stabilize the grain balance and food security of the country.

Winter wheat, winter rye, winter triticale, winter triticale, winter barley, winter hardiness, frost resistance

Varieties of winter crops intended for production usage in Ukraine should have a complex resistance to unfavorable winter factors because only on this condition the realization of the yield potential genetically intrinsic to a variety can become possible. Insufficient adaptability of varieties may lead to a significant decrease in the yield capacity in some years, and sometimes to a complete loss of crops, that is why varieties of winter crops can be recommended for cultivation in production only if they are sufficiently resistant to unfavorable winter conditions [1].

It was found that the genetic potential of variety winter hardiness is realized to varying degrees depending on the ecological and climatic cultivation conditions [2] and the weather conditions of the particular year. Typically in years with favorable winter conditions there are no large differences in the survival of varieties; in severe winters it is also difficult to differentiate varieties, since most of them are killed. In this context, the evaluation of variety frost resistance under controlled conditions is of vital importance upon defining winter hardiness [3, 4].

The National Center of Plant Genetic Resources of Ukraine (NCPGRU) has winter cereals collections, but winter hardiness, including frost resistance, of their samples was not determined and required studying and summarizing resistance levels both of varieties and of cultures in general.

Our studies showed that the most frequent unfavorable autumn and winter factors for the last 20 years were autumn drought (27.3 % of the years), temperature shifts, especially with its sharp drop after the previous thaw periods (68.2 % of the years), and ice cover (18.2 % of the years). Thus, winter cereals varieties recommended for cultivation in the North-Eastern part of Ukraine should be adapted to these factors, and screening of a set of varieties, which are under the state variety trial, for frost resistance and winter hardiness is an urgent task.

Purpose - to determine peculiarities of frost resistance and winter hardiness of winter cereals and their varieties from the NCPGRU collections; to establish a relationship between their resistance; to identify cultures and varieties suitable for cultivation in the North-Eeastern part of Ukraine .

ISSN 0582-5075. Селекція і насінництво. 2014. Випуск 105.

Research Methods. The studies were conducted at the Plant Production Institute nd. a V. Ya. Yuryev of NAAS in 1991-2012. Field experiments were carried out according to the standard procedure [5], statistical processing – according to the method of Dospekhov B. A. [6]. The determination of frost resistance was performed according to the method of V. Ya. Yuryev [7] in our modification and the National Standards of Ukraine 4749:2007 [8]. The resistance was assessed in points as reported in [9, 10].

Winter cereals varieties – soft and hard wheat, triticale, rye and barley from the NCPGRU collections - the material for the studies.

The study years were contrasting by meteorological conditions, which provided an opportunity to comprehensively evaluate winter culture samples by their winter hardiness levels. The years 1991, 1993, 1996, 1997, 2001, 2005, 2008, 2009, and 2011 had favorable overwintering conditions; the years 1992, 1994, 1998, 2002, 2004, and 2007 were close to the long-term average conditions; unfavorable conditions were observed in 1995, 1999, 2006, and 2012; but 2000, 2003, and 2010 were extreme by extent of harmful winter factors.

Results. The variety range of winter hardiness in the winter cereals studied was wide - from 1 point (the lowest) to 9 points (the highest).

The varietal composition of soft winter wheat was the most widely studied (Table 1) – in total about 1,100 samples over the period of 1995-2012. In general, the study expectedly found the largest number of samples with the winter hardiness of 7 points (35 % of the total sample), 6 points (28 %), and 5 points (17 %), since it is known in breeding practice that very high levels of hardiness are determined by genes which are not associated with a high yield potential or high grain quality.

Table 1

Frequency Distribution of Winter Wheat Varieties (%) with Different Levels of Winter Hardiness (Score)

Culture	Score								
	1	2	3	4	5	6	7	8	9
Soft wheat 1995-2012	1	3	6	6	16	27	34	6	1
Hard wheat 1991-2012	8	14	20	31	23	3	1	0	0

The varieties with high winter hardiness (8 and 7 points) accounted for 39 % of the studied samples from the NCPGRU soft winter wheat collection. The varieties with medium winter hardiness (6 and 5 points) - 45 %. 12% of the varieties had low winter hardiness (4 and 3 points), and very low winter hardiness (2 and 1 point) was observed in 4 % of the studied cultivars.

Thus, screening of soft winter wheat varieties indicates that they represented a wide range of frost resistance and winter hardiness; of these varieties the most adapted to overwintering in Ukraine in general, as well as to the conditions of its North- Eastern part were identified. They include varieties of the following breeding institutions: Kharkovskaya 81, Kharkovskaya 63, Kharkovskaya 90, Kharkovskayaiv 105, Kharus, Astet, Vasilina, Alyans, Rozkishna, etc. (Plant Production Institute nd. a V. Ya. Yuryev of NAAS); Odesskaya 267, Dalnitskaya, Vlada, Ukrainka Odesskaya, Antonovka, Turunchuk (Selection and Genetics Institute - National Center of Seed-Growing and Variety Studies NAAS); Podolyanka, Yatran 60, Smuglyanka, etc. (Institute of Plant Physiology and Genetics NASU); Mironovskaya 808, Mironovskaya 61, Mironovskaya Yubileynaya, Voloshkova, Remeslivna, Kolos Mironivschiny, etc. (Myroniv Institute of Wheat nd. a V. M. Remeslo NAAS). Here we recommend these varieties for usage in production conditions for cultivation on farms of all patterns of ownership.

Hard winter wheat is generally characterized by lower winter hardiness in comparison with soft winter wheat [11]. The frequency distribution of hard winter wheat varieties by winter hardiness level is very different from the distribution of soft winter wheat varieties (see Table 1). The vast majority of the varieties belong to the groups with medium and below-medium winter hardiness. This level of hardiness depending on hardening conditions corresponds to the margi-

na; freezing temperatures from -13.5 °C to -15.0 °C (5 points) and from -12.5 °C to -14.0 °C (4 points), respectively. Over the study years no hard winter wheat varieties with very high or high winter hardiness (8-9 points) were found, and only 1 % of the cultivars studied had winter hardiness of 7 points. The varieties with low winter hardiness (3 points) accounted for 20 %, while in soft winter wheat they made up only 5-6 %. The varieties with very low resistance (1-2 points), which in the climatic conditions of the Left Bank forest-steppe are killed or severely injured almost every winter, made up 22 %.

Thus, almost half (42 %) of all the hard winter wheat varieties studied cannot be recommended for cultivation in the Left Bank Forest-Steppe of Ukraine due to the low adaptability to unfavorable winter conditions; even in years with favorable overwintering conditions there is a risk of their significant damage in winter. 31 % of the varieties (4 points) cannot withstand medium-harsh winters, and only 27 % of the varieties (5-7 points) can be allowed to grow in this zone over small areas, because now there are no reliable weather forecasts on stress factor levels of oncoming overwintering. Hard winter wheat can realize its yield potential in the climatic conditions of the Western and South-Western regions of Ukraine.

The most winter-hardy winter cereals are winter triticale [12-14] and winter rye [15]. The winter triticale collection of the National Center of Plant Genetic Resources of Ukraine was characterized by quite uniform distribution of varieties on the winter hardiness scale (Fig. 1). Among the varieties studied the predominant share is occupied by the varieties with winter hardiness of 6 points (23 %) and 7 points (22 %). The winter triticale varieties with high winter hardiness (8 points) accounted for 16 %, and very high winter hardiness (9 points) – 4 %. The varieties in the lower part of the winter hardiness scale were also quite evenly distributed: 11 % of the samples had winter hardiness of 5 points; 6 % of the varieties -4 points, 8 % of the varieties - 3 points, 7 % of the varieties - 2 points, and 3 % of the varieties -1 point. Such distribution is attributed to a wider areal of geographical origin of the winter triticale varieties from the NCPGRU collection, besides Eastern European samples the collection includes varieties from Germany, France, the American continent - Mexico, Canada as well as from Kazakhstan. Due to the wide variety of the samples by winter hardiness in the NCPGRU collection and their involvement in the process of creating new varieties it is possible to provide agricultural enterprises with varieties combining high values of winter hardiness and yield capacity.

Over all the study years no cultivars with low or very low winter hardiness were identified among the winter rye varieties and hybrids (Fig. 1). Only 2 % of the varieties were characterized by below-medium winter hardiness (4 points), 19 % of the varieties had medium hardiness (5 points), and 17 % showed winter hardiness higher than the average (6 points).

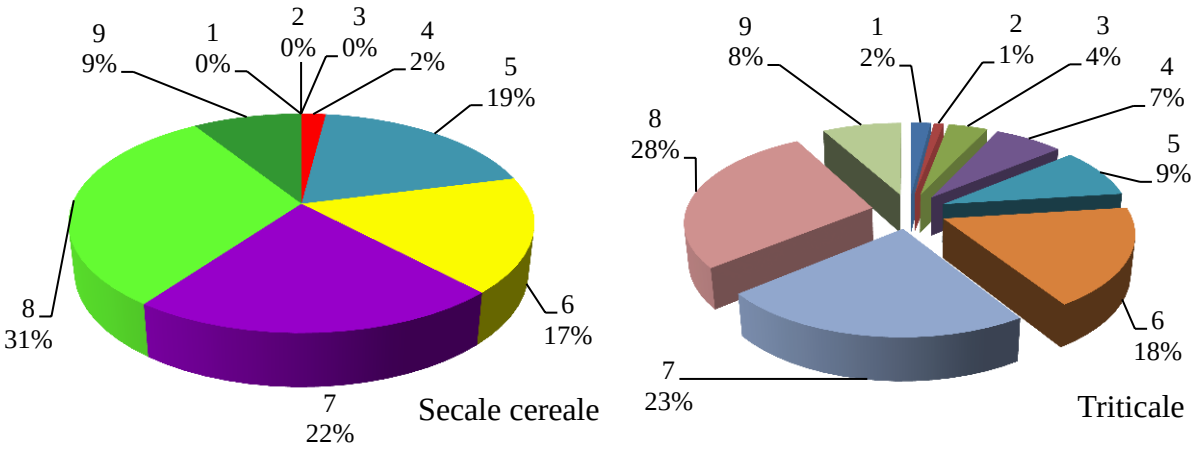

Figure. 1. Frequency Distribution of Winter Triticale and Winter Rye Varieties by Winter Hardiness Level (Score) over the Study Years (2004-2012).

Note: hereinafter: the top number - hardiness score, the bottom number - percentage of manifestation frequency.

At the same time 62 % of all the varieties investigated, and in recent years winter rye hybrids, had increased, high or very high winter hardiness (7 points - 22 %, 8 points - 31 %, 9 points – 9 %); all these varieties are well suited for growing in all the climatic zones of Ukraine essentially under any overwintering conditions, including extreme years. Thus, it was discovered that winter rye is the most adapted to unfavorable overwintering conditions culture among all winter cereals. It is recommended to involve winter rye varieties and hybrids with high or very high levels of winter hardiness in the production and expand areas under this culture, which will provide a secured overwintering of winter cultures even in bad years and will help stabilize the grain balance and food security of the country.

Unlike winter rye, the vast majority of winter barley varieties is referred to the groups of medium, below-medium, low and very low winter hardiness (Fig. 2). Thus, the very low winter hardiness group with scores of 1 and 2 points comprises 14 % of varieties; low winter hardiness group (3 points) - 11 % of the varieties, below-medium winter hardiness group (4 points) - 24 % of the varieties; medium winter hardiness group (5 points) – 24 %; above-medium winter hardiness group (6 points) - 20 % of all the investigated varieties; and the group with increased hardiness (7 points) - 7 %. No variety belonged to the groups with high (8 points) or very high (9 points) winter hardiness over the study years. Thus, the proportion of winter barley varieties unsuitable by their winter hardiness for cultivation in the North- Eastern part of Ukraine (1-4 points) was 49 %, in other words, almost half of all the studied cultivars. 24 % of the varieties can overwinter only in years with medium and stable overwintering conditions, and only 27 % of the varieties can overwinter in years close to the norm by winter conditions. Thus, by frost resistance and winter hardiness winter barley belongs to winter cereals that are the least adapted to overwintering conditions in Ukraine and, in particular, in its North-Eastern part.

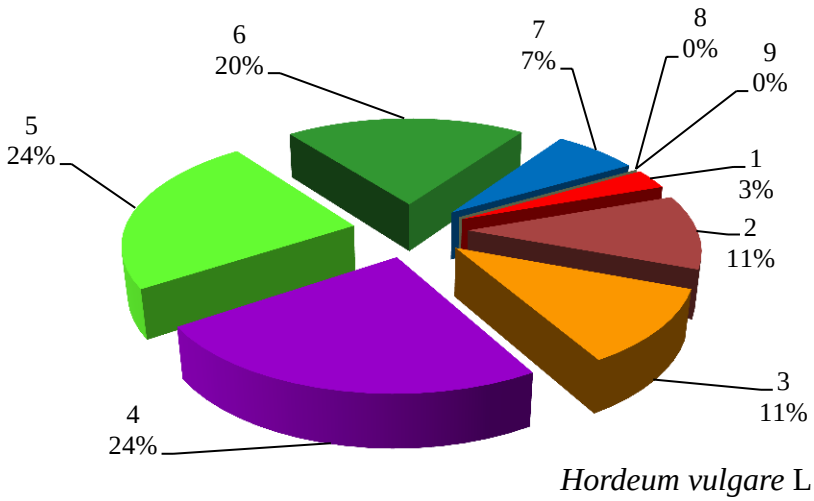

Fig. 2. Frequency Distribution of Winter Barley Varieties by Winter Hardiness Level (Score) over the Study Years (1991-2012)

The obtained data attest to the fact that winter cereals differ in the extent of their winter hardiness and frost resistance. To visualize the relations between them according to winter hardiness traits cluster analysis was conducted (Fig. 3).

Winter rye and winter triticale were the closest cultures on the grounds of winter hardiness elements; they were included in the first sub cluster of the first cluster. Soft winter wheat, forming the second sub cluster of the first cluster, approached them. Winter barley and hard winter wheat were significantly remote from them; they belong to the second cluster with significantly lower levels of winter hardiness.

Since there is currently an active exchange of varieties with other countries, and applications for state variety trials are filed with the purpose of further implementation of foreign winter cereals

varieties in production in our country, it is important to monitor levels of winter hardiness of introduced germplasm with the view of, on the one hand, identification and utilization of high resistance sources, and on the other hand, exclusion of varieties insufficiently adapted to unfavorable climatic conditions of Ukraine from agricultural production

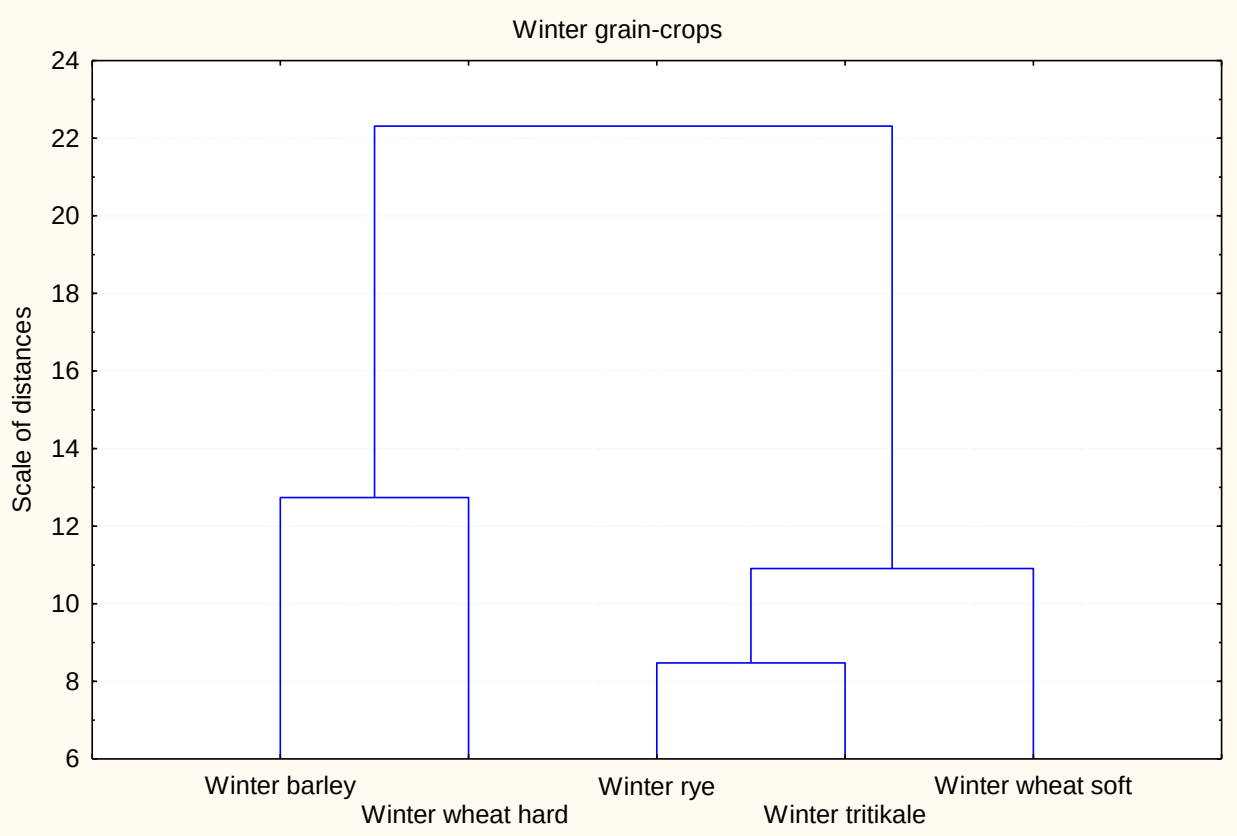

Fig. 3. Relations between Winter Cereals According to the Winter Hardiness Elements

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It was established that Russia, Ukraine and the USA were the sources of the most frost-resistant soft winter wheat varieties. A high level of winter hardiness (8 points on 9-point scale) was determined in the varieties Donskoy Surpriz, Guberniya, Zernogradka 11, Zhemchuzhina Povolzhya, Otrada Sibiri, Orenburgskaya 14, Kazanskaya 237 (Russia), Kharkovskaya 81, Belosnezhka, Driada 1, Volodarka, Vasilina, Astet, Antonovka, Bogdana, Statnaya (Ukraine), KS 93 WGRC 26 (USA). It was found that the majority of soft winter wheat varieties from European countries did not have sufficient winter hardiness for conditions in Ukraine, and when they are used in agricultural production, this feature should be a subject of especially careful monitoring.

Clusterization of the set of soft winter wheat cultivars of different geographical origin on grounds of their winter hardiness identified three main clusters that include most of the studied varieties (Fig. 4). The first subcluster of the first cluster embodies varieties with high levels of winter hardiness originating from Eastern European countries and the American continent: Ukraine, Russia, USA. The second subcluster of the first cluster is represented by samples from Poland and Moldova. The second cluster is predominantly formed by samples from Southern Europe and Asia. Varieties from Romania, Hungary, Georgia, Turkey, and Kazakhstan form the first subcluster, from the Czech Republic, Belarus, as well as Canada - the second subcluster.
The third cluster is formed by varieties, which were close enough to one another by winter hardiness, from central Europe - France, Germany, Slovakia, Bulgaria, Yugoslavia and Austria (the first subcluster). The second subcluster of the third cluster embodies quite distant varieties originating from Turkmenistan.

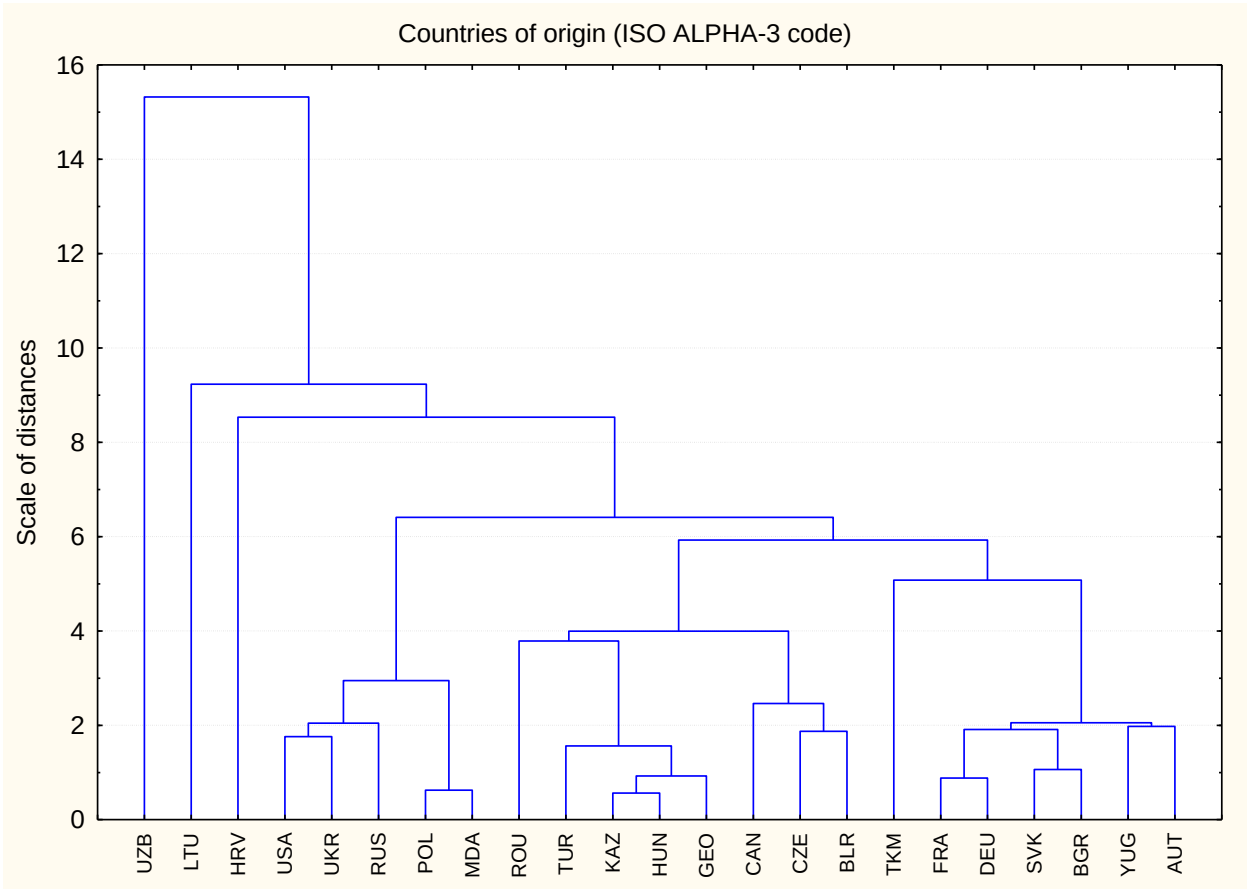

Fig. 4. Grouping of Soft Winter Wheat Varieties Originating from Different Countries According to the Euclidean Distances Calculated from the Winter Hardiness Elements

Varieties originating from Uzbekistan, Lithuania and Croatia formed a separate, largely remote from the other samples, cluster.

Conclusions. The levels of frost resistance and winter hardiness of current winter cereals varieties were determined; their relations to geographical origin of the varieties were assessed.

The necessity of screening for frost resistance and winter hardiness of winter cereals varieties, particularly winter wheat, under controlled conditions was proved. On the basis of the study results the recommendations on areas for growing specific varieties are given. It is recommended to involve winter rye varieties and hybrids in the production and expand areas under this crop that will provide a secured overwintering of winter crops even in years with unfavorable weather conditions and will help stabilize the grain balance and food security of the country.

The relations between winter cereals according the degree of winter hardiness of the varieties were determined, and the levels of their kinship were estimated on this basis.

The assessments of winter hardiness levels of introduced winter crops varieties restrict the introduction of varieties with insufficient frost resistance in the agricultural production, prevents a considerable financial loss of enterprises due to winter-killing of crops, and increases the economical efficiency of winter cereals production.

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АДАПТИВНОСТЬ ОЗИМЫХ ЗЕРНОВЫХ КУЛЬТУР И ИХ СОРТОВ К АБИОТИЧЕСКИМ ФАКТОРАМ ЗИМНЕГО ПЕРИОДА

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В результате исследований был установлен уровень морозостойкости и зимостойкости современных сортов озимых зерновых культур, выявлена его связь с географическим происхождением сорта. Установлено соотношение между озимыми зерновыми культурами по величине зимостойкости сортов и выявлен уровень их родства по этому признаку.

Доказана необходимость проведения скрининга морозостойкости сортов озимых культур в контролируемых условиях, что позволяет ограничить внедрение в сельскохозяйственное производство сортов с недостаточной морозостойкостью, предотвращает значительные материальные потери предприятий из-за зимней гибели посевов и повышает экономическую эффективность производства озимых зерновых культур.

Рекомендуется привлекать в производство сорта и гибриды ржи озимой и расширять площади под этой культурой, что обеспечит гарантированную зимовку озимых даже в неблагоприятные по погодным факторам годы и будет способствовать стабилизации зернового баланса и продовольственной безопасности страны.

Пшеница озимая, рожь озимая, тритикале озимое, ячмень озимый, зимостойкость, морозостойкость

АДАПТИВНІСТЬ ОЗИМИХ ЗЕРНОВИХ КУЛЬТУР ТА ЇХ СОРТІВ ДО АБІОТИЧНИХ ФАКТОРІВ ЗИМОВОГО ПЕРІОДУ

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У результаті досліджень було виявлено рівень морозостійкості та зимостійкості сучасних сортів озимих зернових культур, встановлено його зв'язок з географічним походженням сорту. Встановлено співвідношення між озимими зерновими культурами за величиною зимостійкості сортів і виявлено рівень їх спорідненості за цією ознакою.

Доведено необхідність проведення скринінгу морозостійкості сортів озимих культур в контрольованих умовах, що запобігає значним матеріальним втратам підприємств через зимову загибель посівів і підвищує ефективність виробництва озимих зернових культур. Рекомендується залучати у виробництво сорти та гібриди жита озимого і розширювати площі під цією культурою.

Пшениця озима, жито озиме, тритікале озиме, ячмінь озимий, зимостійкість, морозостійкість