https://doi.org/10.26898/0370-8799-2021-6-4
УДК: 631.527
Тип статьи: оригинальная
Type of article: original

ПОТРЕБНОСТЬ В ПРОДОЛЖИТЕЛЬНОСТИ ЯРОВИЗАЦИИ КОЛЛЕКЦИОННЫХ ОБРАЗЦОВ МЯГКОЙ ОЗИМОЙ ПШЕНИЦЫ

(✉) **Мусинов К.К., Козлов В.Е., Сурначёв А.С., Лихенко И.Е.**
Сибирский научно-исследовательский институт растениеводства и селекции – филиал Федерального исследовательского центра «Институт цитологии и генетики Сибирского отделения Российской академии наук»
Новосибирская область, р.п. Краснообск, Россия
(✉) e-mail: musinov29@gmail.com

Потребность в яровизации – определенное по продолжительности влияние низких положительных температур с целью обеспечения перехода растений к генеративному развитию. Если требование по продолжительности яровизации не выполняется, растение не вступает в стадию образования генеративных органов. Определена яровизационная потребность образцов озимой мягкой пшеницы различного географического происхождения. Дана оценка влияния продолжительности периода яровизации на степень выраженности элементов структуры урожая. Материалом исследования служили 15 сортообразцов озимой мягкой пшеницы различного географического происхождения. Образцы проращивали в бумажных рулонах, затем яровизировали в климатической камере при температуре 3–5 ºС на протяжении 60, 50, 40 сут. По окончании яровизации высаживали в теплице по 10 растений каждого образца. Отмечали даты наступления фенологических фаз: выхода в трубку, колошения, цветения. Для определения основных элементов структуры урожая проведен структурный анализ растений. С увеличением периода яровизации отмечено сокращение межфазных периодов от выхода в трубку до цветения. Влияние сроков яровизации отмечено на проявление признака длина колоса. Установлено, что общее количество стеблей и количество продуктивных стеблей почти у всех сортов уменьшается с увеличением периода яровизации. Выявлены существенные различия между коллекционными сортами в потребности яровизации, обусловленные как их географическим происхождением, так и генотипом растений. У всех изучаемых форм с увеличением периода яровизации в различной степени увеличивался темп развития растения, уменьшались общее количество стеблей, продуктивный стеблестой и длина колоса.

Ключевые слова: озимая пшеница, яровизация, сорт, генеративная стадия развития

THE NEED FOR THE VERNALIZATION DURATION OF SOFT WINTER WHEAT COLLECTION SAMPLES

(✉) **Musinov K.K., Kozlov V.E., Surnachev A.S., Likhenko I.E.**
Siberian Research Institute of Plant Production and Breeding – Branch of the Federal Research Center "Institute of Cytology and Genetics of the Siberian Branch of the Russian Academy of Sciences"
Krasnoobsk, Novosibirsk region, Russia
(✉) e-mail: musinov29@gmail.com

The need for vernalization is a duration-dependent effect of low, positive temperatures in order to ensure the plants' transition to generative development. If the requirement for the duration of germination is not met, the plant will not enter the stage of forming generative organs. The vernalization requirements of winter soft wheat samples of different geographical origins are determined. An assessment of the vernalization period duration influence on the severity of the elements of the yield structure is given. The research material consisted of 15 cultivars of soft winter wheat of various geographic origin. The samples were germinated in paper rolls, then vernalized in a climatic chamber at a temperature of 3–5 ºC for 60, 50, and 40 days. At the end of vernalization, 10 plants of each sample were planted in a greenhouse. The dates of the onset of phenological phases were noted: tube emergence, earing, flowering. To determine the main elements of the yield structure, a structural analysis of plants was carried out. With an increase in the vernalization period, a decrease in the interfa-

cial periods from tube emergence to flowering was noted. The influence of the timing of vernalization was noted on the manifestation of the spike length trait. It was found that the total number of stems and the number of productive stems in almost all varieties decreases with an increase in the period of vernalization. Significant differences between collection varieties in the need for vernalization, due to both their geographical origin and the genotype of plants are revealed. In all the studied forms, with an increase in the period of vernalization, the rate of plant development increased to varying degrees, the total number of stems, the productive stem and the length of the spike decreased.

Keywords: winter wheat, vernalization, variety, generative stage of development

Для цитирования: *Мусинов К.К., Козлов В.Е., Сурначёв А.С., Лихенко И.Е.* Потребность в продолжительности яровизации коллекционных образцов мягкой озимой пшеницы // Сибирский вестник сельскохозяйственной науки. 2021. Т. 51. № 6. С. 31–38. https://doi.org/10.26898/0370-8799-2021-6-4

For citation: Musinov K.K., Kozlov V.E., Surnachev A.S., Likhenko I.E. The need for the vernalization duration of soft winter wheat collection samples. *Sibirskii vestnik sel'skokhozyaistvennoi nauki = Siberian Herald of Agricultural Science*, 2021, vol. 51, no. 6, pp. 31–38. https://doi.org/10.26898/0370-8799-2021-6-4

Конфликт интересов
Авторы заявляют об отсутствии конфликта интересов.
Conflict of interest
The authors declare no conflict of interest.

Благодарность
Работа поддержана бюджетным проектом ИЦиГ СО РАН № 0259-2021-0018.
Acknowledgements
This work was supported by ICG SB RAS Budget Project No 0259-2021-0018.

INTRODUCTION

In the process of evolutionary development in the species of soft winter wheat Triticum aestivum L., a variety of genetic mechanisms have emerged that allow to control the adaptive reactions regulated by the action of temperature [1, 2]. The duration of the growing season in soft wheat is an important adaptive trait that determines the productivity of the plant and resistance to biotic and abiotic factors: drought, low temperatures, diseases and pests [3]. Genes of sensitivity to vernalization (VRN) are the main genetic systems that determine the duration of the growing season as a whole, as well as the duration of the main stages of organogenesis [4-6]. These genetic systems initiate the transition of wheat plants from the vegetative to the generative stage of development. The requirement for vernalization is a certain in duration effect of low positive temperatures in order to ensure the transition of plants to the generative development [7]. If the requirement for the duration of vernalization is not fulfilled, the plant does not enter the stage of formation of generative organs [8]. The need for low positive temperatures helps to avoid the effects of adverse environmental factors in late autumn and winter and to maximize the use of favorable for growth and development spring and summer vegetation period.

Winter wheat varieties have significant differences in the duration of vernalization - from 15 to 60 days and more [9, 10]. It is believed that varieties of different geographical origin are characterized by a certain need in the duration of vernalization [11]. The longer one is typical for the varieties cultivated in the areas with a long winter period. With the extensive use of local varieties, which have been adapted to certain climatic conditions for decades, an increase in the need for germination when moving from south to north was observed [7]. It was found that differences in the duration of the stage of vernalization affect the length of the period from seedlings to earing, drought-, winter- and frost-resistance, the weight of grain per ear, and yield [11, 12]. Reducing the duration of the ripening stage to 30-40 days contributes to a significant increase in yield, but at the same time leads to a decrease in winter- and frost-resistance of modern varieties [10]. Long-term warming provides high adaptability to harsh natural conditions, but interferes with

the rapid development of plants in the spring [13, 14]. Productivity and adaptability of winter soft wheat varieties are closely related to the resistance of plants to stressful wintering conditions. It, in turn, depends on the rate of passage and duration of organogenesis stages, which are largely due to the influence of genetic systems that control the duration of vernalization period.

The purpose of the study was to determine the vernalization requirements of soft winter wheat samples of different geographical origin and to evaluate the effect of the duration of the vernalization period on the elements of the yield structure.

MATERIAL AND METHODS

The work was carried out in the greenhouse of the Institute of Cytology and Genetics of Siberian Branch of the Russian Academy of Sciences (Novosibirsk) in 2020. The material for the research was 15 varieties of soft winter wheat of different geographical origin obtained from VIR and CIMMYT collections, as well as from own working collection. Samples were germinated in paper rolls and then ripened for 60, 50, 40 days in a climatic chamber at 3-5 °C, humidity 85%, illumination 1,500 lux with duration of illumination 8 hours per day. After the end of germination, 10 plants of each sample were planted in the greenhouse. Plants were grown under the temperature regime of 18-20 ºC, illumination of 4-5 thousand lux on a sunny day, 2-3 thousand lux on a cloudy day, and lighting duration of 16 hours per day. The dates of phenological phases: booting, earing, flowering were recorded.

The duration of vernalization was considered sufficient to meet the vernalization requirement if the plants were completely pruned in 50 days after planting. After harvesting, a structural analysis of plants was carried out to determine the main elements of yield structure according to the method of VIR[1]. Statistical calculations were carried out in the Snedecor program.

RESULTS AND DISCUSSION

The studied samples of winter wheat showed a different need for the duration of vernalization. With its increase the reduction of interphase periods from booting to flowering was noted.

Seven samples out of 15 (Krasnobskaya ozimaya, Novosibirskaya 3, Skipetr, Poema, Lars, Czech 9015-15, Utes) do not suffice 40 days to pass the phase of vernalization, so after this period, they did not go to the generative stage of development (see Table 1). In these samples, the increase of the vernalization period from 50 to 60 days led to insignificant (up to 2-4 days) changes in the rate of development.

Differences in the duration of the interphase periods in the remaining 8 samples, which entered the heading phase after 40 days, were more significant and ranged from 2-3 to 8-10 days. Plants of the variety Banko at all stages of vernalization entered the booting phase simultaneously, and only the flowering phase came two days earlier - at 60 days of vernalization. For the collection sample Volzhskaya, the difference between entering the earing and flowering phase at 40 and 60 days of vernalization was 10 days; the difference in the rate of development after vernalization at 50 and 60 days was negligible and varied from 1 to 2 days.

According to two-factor analysis of variance, the influence of the studied factors is reliable (see Table 2). For all the indicators the interaction of the factors "variety" and "vernalization period" was confirmed. It was the interaction of factors that had the greatest influence - from 39,3% (productive stem) to 58,6% (ear length). The share of the influence of the vernalization period was the greatest in the indicator of the ear length - 31.4%.

The results of structural analysis of winter wheat plants of different dates of vernalization show that both the total number of stems and the number of productive stems in almost all varieties decreased with increasing the period of vernalization (see Table 3). On average, the

[1]Replenishment, live preservation and study of the world collection of wheat, aegiplos and triticale: guidelines. A.F. Merezhko, R.A. Udachin, E.V. Zuev et al., SPb, VIR, 1999. - 82 p.

Табл. 1. Продолжительность межфазных периодов в зависимости от продолжительности периода яровизации озимой пшеницы, сут

Table 1. Duration of interphase periods depending on the duration of the winter wheat vernalization period, days

Variety	Origin	Vernalization duration								
		60	50	40	60	50	40	60	50	40
		Booting			Earing			Flowering		
Novosibirskaya 40	Novosibirsk region	27	30	30	34	33	38	38	38	42
Krasnobskaya ozimaya		29	29	–	38	40	–	42	48	–
Novosibirskaya 3		28	28	–	37	37	–	41	42	–
Skipetr	Moscow region	29	30	–	36	37	–	39	42	–
Poema	Vladimir region	27	29	–	34	35	–	38	38	–
Volzhskaya	Ulyanovsk region	28	27	37	34	33	44	38	38	48
Banko	Germany	24	24	24	33	32	33	36	38	38
Lars		30	35	–	36	41	–	41	45	–
Czech 9015-15	Czech Republic	35	37	–	43	45	–	47	50	–
Co 07 W 245	USA	24	28	31	30	32	38	33	37	41
KS 920-709		26	27	30	31	33	35	36	39	41
Utes		30	30	–	34	35	–	39	41	–
SWW 1-135	Kazakhstan	29	29	32	33	35	39	37	39	43
Jcam/Emu	Turkey	29	30	31	34	34	37	39	39	41
Alpu		26	27	30	32	33	37	35	36	42
$LSD_{0,05}$		1,2	1,0	0,9	1,1	1,2	0,8	1,0	1,2	1,1

Примечание. Прочерк означает, что растения не перешли в генеративную стадию развития.

Табл. 2. Двухфакторный дисперсионный анализ показателей продуктивности коллекционных образцов мягкой озимой пшеницы в зависимости от продолжительности периода яровизации

Table 2. Two-factor analysis of variance indicators of soft winter wheat collection samples productivity depending on the duration of the vernalization period

Factor	Trait								$F_{table\ 0.5}$
	Total number of stems		Productive canopy		Ear length		Grain weight per plant		
	Share of the factor's influence, %	$F_{fact.}$	Share of the factor's influence, %	$F_{fact.}$	Share of the factor's influence, %	$F_{fact.}$	Share of the factor's influence, %	$F_{fact.}$	
General	100		100		100		100		
Variety (A)	12,6	5,3	18,3	15,2	4,6	24,4	11,4	7,1	1,8
Vernalization period (B)	13,8	42,9	15,3	86,4	31,4	1162,7	10,8	46,4	3,0
A × B	43,1	14,7	39,3	18,3	58,6	155,2	44,4	16,4	1,0
Error	30,5		27,1		5,4		33,4		

total number of stems decreased from 8.7 (40 days of vernalization) to 6.74 (60 days). The maximum number of stems was recorded at 40 days of vernalization: 12.8 units in the variety Banko and 12.6 units in the variety Novosibirskaya 40.

The average number of productive stems in the studied genotypes was 6.3 for the duration of vernalization of 60 days and increased to 7.5 for 40 days. The response of varieties on this trait to different terms of vernalization was ambiguous. Significant reduction in productive bushiness with an increase in the period of vernalization to 60 days was observed in the varieties Krasnobskaya ozimaya, Skipetr, Lars, Banko. In samples Poema, Volzhskaya, KS 920-709, Utes productive bushiness is practically comparable at all terms of vernalization.

Varieties Lars, Banko and Poema formed the highest crop (6.9-10.0 units). At the same time, the minimum number of unproductive stems was registered in them.

The influence of the terms of vernalization on the length of the ear was noted. With a reduction of terms of vernalization this feature increased. Significant increase in the ear length was observed in Novosibirskaya 40, Volzhskaya, SWW1-135 with an increase in the period of vernalization from 40 to 60 days. In the samples Krasnobskaya ozimaya, Skipetr, Lars, Utes, when reducing the period of vernalization by 10 days (from 50 to 60), the ear length

Табл. 3. Показатели структурного анализа озимой пшеницы в зависимости от продолжительности периода яровизации

Table 3. Indicators of the structural analysis of winter wheat depending on the duration of the vernalization period

Variety	Vernalization duration, days											
	60	50	40	60	50	40	60	50	40	60	50	40
	Total number of stems, pcs.			Productive canopy, pcs.			Spike length, cm			Grain weight per plant, g		
Novosibirskaya 40 (standard)	4,1	7,0	12,6	4,1	6,9	7,9	7,17	7,67	9,79	3,79	7,31	7,63
Krasnobskaya ozimaya	5,1	12,2	–	5,1	7,8	–	8,51	9,43	–	5,66	8,10	–
Novosibirskaya 3	5,7	6,8	–	5,6	6,6	–	8,95	9,55	–	6,82	8,51	–
Skipetr	5,4	13,8	–	5,4	8,0	–	8,27	9,37	–	7,58	10,89	–
Poema	9,3	9,0	–	9	8,4	–	9,36	10,70	–	9,19	9,49	–
Volzhskaya	6,1	6,3	8,5	6,1	6,3	7,9	5,86	6,71	8,07	4,33	4,69	8,23
Banko	7,0	7,5	12,8	6,9	7,5	9,6	5,41	6,84	7,18	3,67	4,57	6,74
Lars	8,2	10,0	–	7,9	10,0	–	8,65	10,00	–	8,74	13,95	–
Czech 9015-15	11,7	11,2	–	6,3	5,8	–	8,69	9,68	–	6,66	5,07	–
Utes	4,8	6,4	–	4,1	4,7	–	6,97	8,71	–	3,20	4,94	–
Co 07 W 245	6,9	5,8	8,7	6,8	5,8	8,4	6,10	6,37	7,72	5,57	5,36	9,04
KS 920-709	6,5	6,3	6,4	6,3	6,2	6,4	6,35	6,74	6,98	6,03	6,20	5,45
SWW 1-135	6,9	4,8	8,4	6,9	4,8	7,1	6,42	7,52	8,26	7,46	5,04	10,10
Jcam/Emu	6,3	7,8	5,9	6,3	7,7	5,9	6,39	7,02	7,65	6,01	6,33	5,88
Alpu	7,1	5,2	6,5	7,1	4,7	6,5	6,77	7,25	6,13	6,49	3,71	7,98
Average value	6,7	8,0	8,7	6,3	6,8	7,5	7,32	8,24	7,70	6,10	6,94	7,63
LSD (5%)	2,0	3,0	2,7	1,6	1,4	1,8	0,58	0,69	0,59	2,02	2,22	2,20

was significantly increased. In Novosibirskaya 3, Poema, Jcam/Emu, Alpu varieties the ear length practically did not change or increased within the error of experiment.

As the period of vernalization decreased, the increase of productive stem and ear length in a number of samples led to an increase in the productivity of plants. Almost all samples with a requirement of 40 days of vernalization had a significant excess of grain weight per plant compared to 60 days. The exceptions were the samples from Turkey Jcam/Emu, Alpu and the sample from the USA KS 920-709. In the samples with a longer period of vernalization, this trend persisted, grain weight per plant at 50 days of vernalization is higher than at 60 days of vernalization.

Two samples from the USA (Co 07 W 245 and KS 920-709) and two samples from Turkey (Jcam/Emu and Alpu) showed relatively similar values of yield structure elements at all stages of vernalization. This indicates that the plants developed relatively similarly at different duration of vernalization. It can be assumed that these varieties have a low need for vernalization: 40 days are enough for a complete transition to the generative stage of development. At the same time, the rate of development slowed down from 2 (Jcam/Emu) to 8 days (Co 07 W 245) compared with 60 days of vernalization.

Four variety samples Novosibirskaya 40, Volzhskaya, Banko, SWW 1-135 also showed a low need for vernalization. However, in contrast to the previously mentioned samples, their indicators of structural analysis at the time of vernalization of 40 days differed significantly from the results obtained with a longer vernalization. In Novosibirskaya 40 and Banko the total number of stems significantly exceeded the number of productive stems, which can negatively affect the density of crops. In varieties Volzhskaya and SWW 1-135, this difference was almost minimal.

In the remaining samples, we observed a sufficient need for vernalization of 50 days. This period was enough for them to go to the generative stage of development. Samples Novosibirskaya 3, Poema, Utes showed comparable data on the elements of the yield structure in the vernalization of 50 and 60 days: at both dates the plants developed equally well. This confirms the fact that these samples did not significantly slow down in development when changing the terms of vernalization.

The varieties Krasnobskaya ozimaya, Skipetr and Lars with 50 days of vernalization formed elements of the yield structure noticeably higher than with a longer period. The varieties Krasnobskaya ozimaya and Skipetr had formed a large number of unproductive stems at 50-days of vernalization in contrast to the variety Lars, where there were no unproductive stems. The variety Czech 9015-15 needed only 50 days of vernalization to reach the generative stage, but this specimen was very active both at 50 and 60 days of vernalization. In both cases, the productive stems were almost 2 times lower than the total number of stems. This may indicate that the requirement of 50-60 days of vernalization for this sample is not fully consistent for optimal development.

The varieties of Siberian selection Novosibirskaya 3 and Krasnoobskaya winter, in contrast to the variety Novosibirskaya 40 showed different need for vernalization, which may be explained by their origin. Novosibirskaya 3 variety was obtained on the basis of interspecific hybridization using winter triticale. Cytological analysis showed the presence of rye chromosome translocation in the plant genome [14]. This translocation was also noted in the variety Krasnobskaya ozimaya, whose pedigree includes the variety Novosibirskaya 3.

CONCLUSION

The study of the need for vernalization of winter wheat collection samples revealed significant differences between the varieties due to both their geographical origin and plant genotype. In all studied forms with increasing of the period of vernalization the development rate increased to a different extent, the total number of stems, productive stem and ear length decreased. At 60 days of vernalization the productive stalks of the samples were close to the total number of stems. This ratio decreases as the germination period decreases. At long-term

vernalization (up to 60 days) in most samples the grain weight from plants decreased compared with vernalization at 50 and 40 days.

СПИСОК ЛИТЕРАТУРЫ

1. *Файт В.И.* Генетический контроль продолжительности яровизации сортов озимой пшеницы // Экологическая генетика. 2006. Т. 4. № 2. С. 29–36
2. *Файт В.И., Симоненко Л.К., Мокану Н.В., Попова Н.В.* Хромосомная локализация генов контроля продолжительности яровизации (vrd) озимой мягкой пшеницы // Генетика. 2007. Т. 43. № 2. С. 202–208.
3. *Chumanova E.V., Efremova T.T., Kruchinina Y.V., Pershina L.A.* Development and investigation of common wheat lines of winter cultivar Bezostaya 1 with combinations of dominant alleles of VRN-1 loci // Vavilov Journal of Genetics and Breeding. 2018. Vol. 22 (8). P. 951–956. DOI: 10.18699/VJ18.437.
4. *Стельмах А.Ф., Файт В.И.* Разнообразие генотипов современных сортов озимой мягкой пшеницы по потребности в яровизации и фоточувствительности // Молекулярная и прикладная генетика. 2011. Т. 12. С. 15–17
5. *Киселева А.А., Салина Е.А.* Генетические механизмы формирования времени колошения мягкой пшеницы // Генетика. 2018. Т. 54. № 4. С. 381–396. DOI: 10.7868/S001667581804001X.
6. *Пирыч А.В., Булавка Н.В., Юрченко Т.В.* Фотопериодическая чувствительность и яровизационная потребность сортов мягкой пшеницы озимой (*Triticum aestivum* L.) мироновской селекции // Зернові культури. 2018. Т. 2. № 2. С. 261–266. DOI: 10.31867/2523-4544/0034.
7. *Булавка Н.В.* Яровизационная потребность сортов озимой мягкой пшеницы в связи с их морозоустойчивостью // Земледелие и селекция в Беларуси. 2014. № 50. С. 383–392.
8. *Košner J., Pánková K.* Vernalisation Response of Some Winter Wheat Cultivars // Czech Journal of Genetics and Plant Breeding. 2002. Vol. 38. N 3–4. P. 97–103.
9. *Файт В.И.* Изогенные линии озимой пшеницы по генам контроля продолжительности яровизации // Информационный вестник ВОГиС. 2006. Т. 10. № 3. С. 580–587.
10. *Файт В.И.* Эффекты генов контроля продолжительности яровизации (Vrd) по агрономическим признакам в озимой мягкой пшенице // Цитология и генетика. 2007. № 5. С. 18–26.
11. *Булавка Н.В., Голик Л.Н.* Яровизационная потребность современных сортов пшеницы мягкой озимой (*Tritikum aestivum* L.) // Сортовивчення та охорона прав на сорти рослин. 2007. № 2 (6). С. 54–59.
12. *Потокина Е.К., Кошкин В.А., Алексеева Е.А.* Комбинация аллелей генов PPD и Vrn определяет сроки колошения у сортов мягкой пшеницы // Вавиловский журнал генетики и селекции. 2012. Т. 16. № 1. С. 77–86.
13. *Дубинина О.А.* Устойчивость озимой пшеницы к основным стрессовым факторам окружающей среды и погодных условий (обзор) // Зерновое хозяйство России. 2017. № 1. С. 23–26.
14. *Степочкин П.И., Пономаренко В.И., Першина А.А., Осадчая Т.С., Трубачева Н.В.* Использование отдаленной гибридизации для создания селекционного материала озимой пшеницы // Достижения науки и техники АПК. 2012. № 6. С. 37–38.

REFERENCES

1. Fait V.I. Genetic control of vernalization requirement duration of winter wheat cultivars. *Ekologicheskaya genetika = Ecological genetics*, 2006, vol. 4, no. 2, pp. 29–36. (In Russian).
2. Fait V.I., Simonenko L.K., Mokanu N.V., Popova N.V. Chromosomal location of genes for vernalization requirement duration (vrd) in winter bread wheat. *Genetika = Russian Journal of Genetics*, 2007, vol. 43, no. 2, pp. 202–208. (In Russian).
3. Chumanova E.V., Efremova T.T., Kruchinina Y.V., Pershina L.A. Development and investigation of common wheat lines of winter cultivar Bezostaya 1 with combinations of dominant alleles of VRN-1 loci. *Vavilov Journal of Genetics and Breeding*, 2018, no. 22 (8), pp. 951–956. DOI: 10.18699/VJ18.437.
4. Stel'makh A.F., Fait V.I. Variety of genes of modern winter bread wheat cultivars for requirement in vernalization and photosensitivity. *Molekulyarnaya i prikladnaya genetika = Molecular and applied genetics*, 2011, vol. 12, pp. 15–17. (In Russian).
5. Kiseleva A.A., Salina E.A. Genetic regulation of common wheat heading time. *Genetika = Russian Journal of Genetics*, 2018, vol. 54, no. 4, pp. 381–396. (In Russian). DOI: 10.7868/S001667581804001X.
6. Pirych A.V., Bulavka N.V., Yurchenko T.V. Photoperiodic sensitivity and vernalization requirement of winter wheat varieties (Triticum aestivum L.) of Myronivka breeding. *Zernovi*

kul'turi = Grain crops, 2018, vol. 2, no. 2, pp. 261–266. (In Belarus). DOI: 10.31867/2523-4544/0034.
7. Bulavka N.V. Vernalization requirement of winter soft wheat varieties in relation to their winter hardiness. *Zemledelie i selektsiya v Belarusi = Agriculture and selection in Belarus,* 2014, no. 50, pp. 383–392. (In Russian).
8. Košner J., Pánková K. Vernalisation Response of Some Winter Wheat Cultivars. *Czech Journal of Genetics and Plant Breeding*, 2002, vol. 38, no. 3–4, pp. 97–103.
9. Fait V.I. Near- isogenic lines of the genes controlling differences in duration of vernalization in winter common wheat. *Informatsionnyi vestnik VOGiS = Vestnik VOGiS (Information Bulletin of Vavilov Society for Geneticists and Breeding Scientists)*, 2006, vol. 10, no. 3, pp. 580–587. (In Russian).
10. Fait V.I. Effects of genes for controlling the duration of vernalization (Vrd) on agronomic traits in winter soft wheat. *Tsitologiya i genetika = Cytology and genetics*, 2007, no. 5, pp. 18–26. (In Russian).
11. Bulavka N.V., Golik L.N. Vernalization requirement of winter bread wheat modern varieties (Triticum aestivum L.). *Sortovivchennya ta okhorona prav na sorti roslin*, 2007, no. 2 (6), pp. 54–59. (In Belarus).
12. Potokina E.K., Koshkin V.A., Alekseeva E.A. The combination of PPD and Vrn gene alleles determines the heading date in common wheat varieties. *Vavilovskii zhurnal genetiki i selektsii = Vavilov Journal of Genetics and Breeding*, 2012, vol. 16, no. 1, pp. 77–86. (In Russian).
13. Dubinina O.A. Winter wheat resistance to main stress factors of environment and weather (review). *Zernovoe khozyaistvo Rossii = Grain economy of Russia*, 2017, no. 1, pp. 23–26. (In Russian).
14. Stepochkin P.I., Ponomarenko V.I., Pershina A.A., Osadchaya T.S., Trubacheva N.V. Utilization of distant hybridization for development of breeding material of winter wheat. *Dostizheniya nauki i tekhniki APK = Achievements of Science and Technology of AICis*, 2012, no. 6. pp. 37–38. (In Russian).

ИНФОРМАЦИЯ ОБ АВТОРАХ

✉ **Мусинов К.К.,** младший научный сотрудник; **адрес для переписки:** Россия, 630501, Новосибирская область, р.п. Краснообск, ул. С-100, зд. 21, e-mail: musinov29@gmail.com

Козлов В.Е., кандидат сельскохозяйственных наук, старший научный сотрудник

Сурначёв А.С., младший научный сотрудник

Лихенко И.Е., доктор сельскохозяйственных наук, заведующий лабораторией

AUTHOR INFORMATION

✉ **Kenzhbek K. Musinov,** Junior Researcher, **address:** S-100 St., building 21, Krasnoobsk, Novosibirsk Region, 630501, Russia; email: musinov29@gmail.com

Viktor E. Kozlov, Candidate of Science in Agriculture, Senior Researcher

Alexei S. Surnachev, Junior Researcher

Ivan E. Likhenko, Doctor of Science in Agriculture, Head of laboratory

Дата поступления статьи / Received by the editors 25.08.2021
Дата принятия к публикации / Accepted for publication 07.11.2021
Дата публикации / Published 27.12.2021