The interphase period "germination–heading" of 8x and 6x triticale with different dominant *Vrn* genes

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Abstract. The existing spring forms of wheat-rye amphiploids are characterized by late maturity due to the long duration of the interphase period "germination–heading". The manifestation of this trait is influenced by *Vrn-1* genes. Their dominant alleles also determine the spring type of development. The results of studying the interphase period "germination–heading" of spring octaploid and hexaploid forms of triticale created for use in research and breeding programs under the conditions of forest-steppe of Western Siberia are given in this article. The interphase period of the primary forms 8xVrnA1, 8xVrnB1 and 8xVrnD1 obtained by artificial doubling of the chromosome number of the wheat-rye hybrids made by pollination of three lines of the soft wheat 'Triple Dirk' – donors of different dominant *Vrn-1* genes – by a winter rye variety 'Korotkostebel'naya 69' was determined under the field conditions in the nursery of octaploid (8x) triticale. In the nursery of hexaploid triticale, this trait was studied in the populations of hybrids obtained by hybridization of these three primary forms of octaploid triticale with the hexaploid winter triticale variety 'Sears 57'. In the offspring of crossing 8xVrnD1 × 'Sears 57', spring genotypes of 6x triticale bearing *Vrn-D1* were selected. This fact was determined by PCR. It means that the genetic material from the chromosome of the fifth homeologous group of the D genome of the bread wheat is included in the plant genotypes. This genome is absent in the winter 6x triticale 'Sears 57'. The grain content of spikes of the created hexaploid forms of triticale is superiour to that of the maternal octaploid triticale forms. It was shown that plants of the hybrid populations 8xVrnA1 × 'Sears 57' and 8xVrnD1 × 'Sears 57' carrying the dominant alleles *Vrn-A1a* and *Vrn-D1a*, respectively, have a shorter duration of the "germination–heading" interphase period than the initial parental forms of primary 8x triticale. The short interphase period of "germination–heading" of the 6x triticale is a valuable breeding trait for the creation of early maturing and productive genotypes of triticale.
Key words: octaploid; hexaploid triticale; interphase period "germinarion–heading"; *Vrn-1* genes; hybrids.

Межфазный период «всходы–колошение» у 8x и 6x тритикале с различными доминантными генами *Vrn*

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Аннотация. Существующие коллекционные формы яровых пшенично-ржаных амфиплоидов характеризуются позднеспелостью из-за большой продолжительности межфазного периода «всходы–колошение». На проявление этого признака влияют гены *Vrn-1*, аллели которых в доминантном состоянии обусловливают яровой тип развития. В статье приведены результаты изучения межфазного периода «всходы–колошение» у яровых окта- и гексаплоидных форм тритикале, создаваемых для использования в исследовательских и селекционных программах в условиях лесостепи Западной Сибири. Исследования проводили в питомнике октаплоидных (8x) тритикале в полевых условиях у первичных форм 8xVrnA1, 8xVrnD1 и 8xVrnB1, полученных искусственным удвоением числа хромосом пшенично-ржаных гибридов от опыления пыльцой озимой ржи (сорт Короткостебельная 69) трех линий мягкой пшеницы Triple Dirk – доноров разных доминантных генов *Vrn-1*. В питомнике гексаплоидных (6x) тритикале изучали этот признак растений в популяциях гибридов от скрещиваний трех форм первичных октаплоидных тритикале с гексаплоидным озимым сортом тритикале Сирс 57. С помощью молекулярных маркеров у гибридов определен аллельный состав генов *Vrn-1*. В потомстве, полученном от скрещивания 8xVrnD1 × Сирс 57, выделены и определены методом ПЦР генотипы яровых растений 6x тритикале с доминантным геном *Vrn-D1*. Данный факт свидетельствует о включении в них генетического материала хромосомы пятой гомеологичной

группы генома D мягкой пшеницы, входящего в геномный состав октаплоидного тритикале. Этот геном отсутствует в озимом 6*x* тритикале Сирс 57. У созданных гексаплоидных форм тритикале озерненность колоса была лучше, чем у материнских октаплоидных. Показано, что растения из гибридных популяций 8*xVrnA1*×Сирс 57 и 8*xVrnD1*×Сирс 57, несущие доминантные аллели *Vrn-A1a* и *Vrn-D1a* соответственно, обладают более короткой продолжительностью межфазного периода «всходы–колошение», чем исходные родительские формы первичных 8*x* тритикале. Короткий межфазный период «всходы–колошение» у полученных 6*x* тритикале является селекционно ценным признаком для создания раннеспелых и продуктивных генотипов тритикале.

Ключевые слова: октаплоидные; гексаплоидные тритикале; межфазный период «всходы–колошение»; гены *Vrn-1*; гибриды.

Introduction

Hundreds of winter and spring varieties and collection forms of triticale (×*Triticosecale* Wittmack) or wheat-rye amphiploid (WRA) with genomes of wheat (*Triticum* spp.) and rye (*Secale* spp.) have been made for more than 130-year history of this artificial crop. According to the latest data of the world organization FAO, in 2017, the total area of this crop reached almost 4.17 million hectares and grain production was 15.6 million tons. In the Russian Federation the area of crops decreased up to 171.7 thousand hectares in 2017, compared with the maximum value 274.5 thousand hectares in 2014. Grain yield for those years amounted to 500.7 thousand tons and 654.1 thousand tons, respectively (http://www.fao.org/faostat/ru/#data/QC/visualize). This circumstance is due to a decrease in breeding work and creation of varieties of wheat-rye amphiploids in the Russian Federation in recent years.

Hexaploid (6*x*) forms of triticale (B^uB^uAARR, $2n = 42$) are mainly used for agricultural practice. They are more cytogenetically stable and fertile compared to octaploid (8*x*) (B^uB^uAADDRR, $2n = 56$) ones (Lukaszewski, Gustafson, 1987). However, there are some reports of successful cultivation of 8*x* triticale (Cheng, Murata, 2002).

In Siberia, this crop has not yet been cultivated on a large scale, since selection of spring triticale forms has not been conducted. Spring triticale samples from the world collection of VIR are late-maturing and winter varieties of European selection do not have good winter hardiness and often do not give good grain yield under severe climatic conditions of Siberia. Two winter short-stemmed varieties Sears 57 and Cecad 90 have been created in Siberian Research Institute of Plant Production and Breeding – Branch of the Federal Research Center the Institute of Cytology and Genetics of the Siberian Branch of the Russian Academy of Sciences (SibRIPP&B – Branch of ICG SB RAS) for grainforage use. They occupy only several thousands hectares. More than a dozen of spring varieties have been created in Russia (Tyslenko et al., 2016), but there are no Siberian varieties of spring triticale yet, although spring crops yield yearly, unlike winter ones. In order to carry out breeding work with spring triticale successfully, it is necessary to comprehensively study the characteristics associated with the productivity and adaptability of plants, including those related to the type and duration of plant development.

The type of plant development (spring, winter, alternative), and the duration of the growing period are controlled by *Vrn* (response to vernalization) genes. The key role in wheat species is played by dominant *Vrn-1* genes: *Vrn-A1*, *Vrn-B1*, and *Vrn-D1* (Yan et al., 2003; Muterko et al., 2015, 2016; Shcherban et al., 2015; Dixon et al., 2019). They are in the long arms of 5A, 5B, and 5D chromosomes of three genomes of soft wheat A, B, and D, respectively. There are also the *Vrn-D4* gene located in the centromere region of 5D chromosome (Yoshida et al., 2010; Kippes et al., 2015) and the *Vrn-B3* gene located in the short arm of chromosome 7B (Yan et al., 2006). Studies have revealed the presence of several alleles in each of the *Vrn-1* genes (Yan et al., 2004; Fu et al., 2005; Shcherban et al., 2012; Muterko et al., 2015). The dominant state of any of these genes leads to the spring type of development, and the recessive state leads to the winter type (Pugsley, 1971; Worland, 1996; Yan et al., 2003, 2004, 2006; Fu et al., 2005). The type of plant development of rye is controlled by the *Vrn-R1* gene located in the long arm of the chromosome 5R (Plaschke et al., 1993).

Vrn-1 genes of spring wheat varieties mainly determine the duration of the phases from tillering to tube formation. Duration of the period from germination to heading depends on the allelic state of *Vrn-1* genes. It was shown that the plants containing *Vrn-B1c* allele formed spikes earlier than those with *Vrn-B1a* allele (Emtseva et al., 2013). The expression of *Vrn-A1a* allele leads to earlier earing than that of *Vrn-B1a* or *Vrn-B1c* allele (Kruchinina et al., 2017). The dominant gene *Vrn-A1* of soft wheat *T. aestivum* L. has the greatest effect and the dominant gene *Vrn-B1* has the smallest one (Košner, Pánková, 2004). In octaploid triticale lines created on the basis of almost isogenic on dominant genes *Vrn-1* lines of soft wheat Triple Dirk, the plants with *Vrn-A1a* and *Vrn-D1a* genes formed spikes earlier than those with the *Vrn-B1a* gene (Stepochkin, Emtseva, 2017).

The purpose of this article is to study the duration of the interphase period "germination–heading" of created in SibRIPP&B – Branch of ICG SB RAS spring octaploid and hexaploid triticale forms having different dominant *Vrn-1* genes under conditions of the forest-steppe of Western Siberia.

Materials and methods

The duration of the interphase period "germination–heading" of octaploid (8*x*) and hexaploid (6*x*) triticales with different dominant *Vrn-1* genes affecting the duration of the vegetation period of plants was studied in generations: F_1 – in 2014, F_3 – in 2016, F_4 – in 2017, F_5 – in 2018 and F_6 – in 2019.

Three primary 8*x* triticale forms were made in SibRIPP&B – Branch of ICG SB RAS by crossing almost isogenic lines of soft wheat Triple Dirk D, Triple Dirk B and Triple Dirk E (Pugsley, 1971, 1972) with winter diploid rye variety Korotkostebel'naya 69 and by subsequently doubling the chromo-

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some number in wheat-rye hybrids (Stepochkin, 2009, 2017). The wheat lines are the sources and donors of dominant genes *Vrn-A1*, *Vrn-B1* and *Vrn-D1*, respectively. The allelic compositions of *Vrn-1* genes of three 8x WRA are *Vrn-A1a*, *vrn-B1*, *vrn-D1*, *vrn-R1* (8xVrnA1); *vrn-A1*, *Vrn-B1a*, *vrn-D1*, *vrn-R1* (8xVrnB1); *vrn-A1*, *vrn-B1*, *Vrn-D1a*, *vrn-R1* (8xVrnD1).

Spring hexaploid forms of triticale were made by selecting early-maturing plants in the offspring of F_3–F_4 hybrids between primary 8x WRA and winter 6x triticale Sears 57 carrying recessive genes *vrn-A1*, *vrn-B1*, *vrn-R1* (Fig. 1). The allelic composition of *Vrn-1* genes in plants of hybrid populations and parent forms was determined by PCR using allele-specific primers. The structure of primers to *Vrn-1* genes and the conditions of PCR are described in articles (Potokina et al., 2012; Likhenko et al., 2015).

Genomic DNA was isolated according to the previously described method (Likhenko et al., 2015). PCR was performed on a BIO-RAD T-100 Thermal Cycler (USA) amplificator in a total reaction mixture of 20 μl, including DNA (50–100 ng/μl) – 1 μl, 10× buffer for Taq polymerase (650 mM Tris-HCl (pH 8.9); 160 mM $(NH_4)_2SO_4$; 25 mM $MgCl_2$; 0.5 % Tween 20) – 2 μl, dNTPs – 2 μl, direct and reverse primer – 0.5 μl each, Taq polymerase (1 unit/μl) – 1 μl, H_2O – up to the final volume of 20 μl. The separation of PCR products was performed by electrophoresis in 1 % agarose gel with the addition of ethidium bromide.

Sowing in the field soil was carried out by hand in the third decade of May (May 21–24 in different years, depending on the weather) in rows of 0.8 m long, 50 seeds in a row on the isolated from other grain crops experimental plot of SibRIPP&B – Branch of ICG SB RAS, where a three–field crop rotation was maintained: vegetables – fallow soil – triticale. During the growing season, phenological observations and evaluations were carried out. Statistical processing of the results was performed using the Student's *t*-test (Dospekhov, 1985).

Results

The evaluation of plants in populations of primary octaploid WRA showed that the duration of the interphase period "germination–heading" in triticale lines 8xVrnA1 and 8xVrnD1 in

Fig. 1. Spikes of spring octaploid triticale plants: 8xVrnA1 (*1*), 8xVrnD1 (*2*), 8xVrnB1 (*3*) and winter hexaploid triticale Sears 57 (*4*).

2018 and 2019 was shorter than that in 2014, 2016 and 2017 (Table 1). In 2019, triticale 8xVrnA1 had the shortest "germination–heading" period (52.9 days) among all octaploid WRA, while 8xVrnB1 had the longest one (72.5 days). This period of the maternal line 8xVrnD1 lasted 53.8 days. In 2019 hexaploid plants of the hybrid population 8xVrnA1 × 6x Sears 57 in comparison with other hexaploid forms had the shortest duration of this period (47.3 days) and plants of the population 8xVrnB1 × 6x Sears 57 had the longest one (57.8 days). Unlike the maternal forms, this period at 6x level was 6 and 14 days shorter. 6x plants made by crossing 8xVrnD1 × Sears 57 had the period of development before earing of 53.4 days and did not significantly differ from the spring octaploid parent. When comparing the data of all years of research, one can note that the selection of the most early-maturing plants in each generation led to a significant reduction of the duration of the period from germination to heading of both hexaploid and maternal octaploid triticale forms except for the parental form 8xVrnB1. It did not show significant changes in the duration of this period during all years of research.

Ear morphology of hexaploid triticale plants differs from that of the original octaploid forms (Fig. 2). All octaploid triticale lines are awnless, and the hexaploid forms have, like the paternal winter variety Sears 57, small rudiments of the

Table 1. Duration of the interphase period "germination–heading" of hybrid hexaploid and maternal octaploid triticale plants with different dominant *Vrn-1* genes

Hybrids and maternal triticale forms	Duration of the interphase period "germination–heading", days (m ± sem)				
	2014	2016	2017	2018	2019
8xVrnA1 × Sears 57	69.2 ± 1.3*	66.1 ± 3.3	55.0 ± 1.9**	45.1 ± 2.5*	47.3 ± 1.9*
8xVrnD1 × Sears 57	75.9 ± 2.1**	68.3 ± 1.7	63.3 ± 2.4	55.2 ± 6.7	53.4 ± 1.7
8xVrnB1 × Sears 57	79.6 ± 4.4	71.7 ± 1.5	68.6 ± 3.4	56.4 ± 2.1**	57.8 ± 1.5**
8xVrnA1	65.2 ± 1.7	65.1 ± 2.0	61.7 ± 1.1	51.0 ± 1.8	52.9 ± 1.4
8xVrnD1	67.0 ± 1.9	66.3 ± 0.7	63.9 ± 1.0	49.5 ± 2.6	53.8 ± 2.1
8xVrnB1	73.6 ± 1.9	71.3 ± 0.9	69.0 ± 3.1	71.2 ± 4.3	72.5 ± 1.6

* $p < 0.05$; ** $p < 0.01$ – significant differences between a hybrid and its parental form of 8x triticale.

Fig. 2. Ears of triticale plants: octaploid 8*xVrnA1* (*1*), 8*xVrnB1* (*2*), 8*xVrnD1* (*3*); hexaploid made from crossing 8*xVrnA1*×Sears 57 (*4*), 8*xVrnB1*×Sears 57 (*5*), 8*xVrnD1*×Sears 57 (*6*).

awns, mainly at the end of the spike. The octaploid amphiploid 8*xVrnD1* as well as the hexaploid 6*xVrnD1* derived from it (hybrid 8*xVrnD1*×Sears 57) have hairy spikes – a trait inherited from Triple Dirk E wheat (*VrnD1*).

For practical use, it is important to note that ears of all hexaploid plants are denser and contain more kernels than those of 8*x* triticale (Table 2). In 2019, the number of kernels in ears of 6*x* forms varied from 25.8 grains of hybrids 8*xVrnB1*×Sears 57 up to 36.4 grains of hybrids 8*xVrnA1*×Sears 57, and in octaploid lines – from 9.1 grains in ears of 8*xVrnD1* to 16.4 grains in ears of 8*xVrnA1*. Weight of grains from ear varied in 6*x* forms from 0.76 ± 0.10 to 1.28 ± 0.21 g, and in 8*x* forms – from 0.24 ± 0.03 to 0.50 ± 0.13 g. In addition, grain unit in hexaploid forms is slightly higher than that in 8*x* WRA. No significant differences between hexaploid and octaploid triticale forms were found for the weight of 1000 grains.

The combination of early ripeness, which is largely due to the duration of the interphase period "germination–heading", and the number of grains of ear makes two hexaploid forms 8*xVrnA1*×Sears 57 and 8*xVrnD1*×Sears 57 promising for further breeding work.

The selected early-maturing hexaploid plants were analyzed by PCR using allele-specific primers for *Vrn-1* genes. Their parents – the winter variety triticale Sears 57 and the octaploid maternal forms were taken for comparison (Fig. 3). The analysis showed that the winter variety Sears 57 carries recessive alleles *vrn-A1*, *vrn-B1* and *vrn-D1*. The maternal forms had the following allelic composition: 8*xVrnA1* – *Vrn-A1a*, *vrn-B1*, *vrn-D1*; 8*xVrnB1* – *vrn-A1*, *Vrn-B1a*, *vrn-D1*; 8*xVrnD1* – *vrn-A1*, *vrn-B1*, *Vrn-D1a*. The offspring from the 8*xVrnA1*×Sears 57 cross was heterozygous on the *Vrn-A1* gene because they contained two alleles – *Vrn-A1a* and *vrn-A1*. In addition, a recessive allele *vrn-B1* was revealed, and the alleles of the *Vrn-D1* gene were not determined due to the lack of an amplification product. Plants of the hybrid population 8*xVrnB1*×Sears 57 have a recessive allele *vrn-A1*, and the *Vrn-D1* gene was not amplified in them. As for the *Vrn-B1* gene, the plants are heterozygous and have two alleles *Vrn-B1a* and *vrn-B1*. Two recessive alleles – *vrn-A1*, *vrn-B1*, and one dominant allele – *Vrn-D1a* – were identified in plants obtained from crossing 8*xVrnD1*×Sears 57.

Discussion

Secondary spring 6*x* triticale breeding samples possess dominant alleles of *Vrn-1* genes and were made by hybridization of primary 8*x* WRA carrying dominant alleles of *Vrn-1* genes with a winter 6*x* WRA carrying recessive alleles. At the 6*x* level in the offspring of hybrids in all the studied generations, their *Vrn-1* genes retain almost the same ranking (8*xVrnA1*×6*x* Sears 57 > 8*xVrnD1*×6*x* Sears 57 > 8*xVrnB1*×6*x* Sears 57) as at the 8*x* level in triticale (8*xVrnA1* $\geq$ 8*xVrnD1* > 8*xVrnB1*) in terms of the effect on the reduction of the "germination–heading" period. The original Triple Dirk lines have the same ranking of these genes (Stepochkin, 2009; Stepochkin, Emtseva, 2017). Thus, the effect of the dominant alleles *Vrn-A1a* and *Vrn-D1a* leads to a shorter interphase period compared to the effect of the *Vrn-B1a* allele. It is known that in addition to the *Vrn-D1* gene, the *Vrn-D4* gene localized in the chromosome 5D can significantly affect the duration of the period from germination to earing (Kippes et al., 2014). Theoretically, it is possible that along with the *Vrn-D1* gene, a *Vrn-D4* gene can be inserted. However, we exclude this pos-

Table 2. Some ear quantitative characteristics of 8*x* and 6*x* triticale with different *Vrn-1* genes, 2019

Triticale names	Ear density, spikelet number/1 cm	Ear kernel number	Ear kernel weight, g	Weight of 1000 kernels, g	Grain unit, g/1000 cm³
8*xVrnA1*	2.01 ± 0.06[*]	16.4 ± 3.1[**]	0.50 ± 0.13[*]	30.5 ± 4.0	563 ± 16[*]
8*xVrnB1*	1.89 ± 0.07[**]	10.2 ± 2.7[**]	0.25 ± 0.04[**]	25.4 ± 4.0	538 ± 2[*]
8*xVrnD1*	1.95 ± 0.06[**]	9.1 ± 1.4[**]	0.24 ± 0.03[**]	26.7 ± 2.0	578 ± 13
8*xVrnA1*×Sears 57	2.52 ± 0.08	36.4 ± 4.4	1.28 ± 0.21	35.1 ± 2.5	650 ± 10
8*xVrnB1*×Sears 57	2.60 ± 0.04	25.8 ± 2.2	0.76 ± 0.10	29.2 ± 2.1	591 ± 8
8*xVrnD1*×Sears 57	2.74 ± 0.07	36.1 ± 3.1	1.20 ± 0.10	33.1 ± 1.4	589 ± 12
Sears 57 (6*x*)	2.87 ± 0.04	30.0 ± 1.9	0.92 ± 0.17	30.8 ± 6.1	542 ± 9

[*] $p < 0.05$; [**] $p < 0.01$ – significant differences between a hybrid and its parental form of 8*x* triticale.

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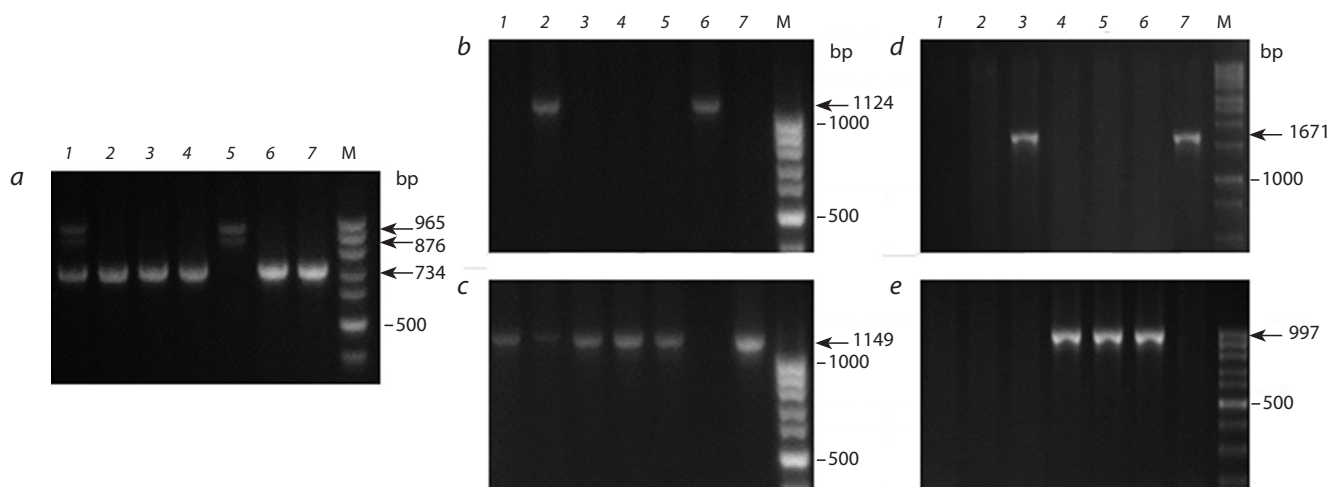
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Fig. 3. Amplification of the PCR products using primers for *Vrn-1* genes in hexaploid hybrids of triticale and parental forms: (*a*) *Vrn-A1a* (965 + 876 bp) and *vrn-A1* (734 bp); (*b*) *Vrn-B1a* (1124 bp); (*c*) *vrn-B1* (1149 bp); (*d*) *Vrn-D1a* (1671 bp); (*e*) *vrn-D1* (997 bp).

1–3 – hybrids: 8*xVrnA1* × Sears 57, 8*xVrnB1* × Sears 57 and 8*xVrnD1* × Sears 57, respectively; *4* – winter variety Sears 57; *5–7* – spring octaploid forms: 8*xVrnA1*, 8*xVrnB1* and 8*xVrnD1*, respectively; M – marker of the length of DNA fragments (*a–c, e* – 100 bp ladder; *d* – 1000 bp ladder).

sibility, because to make primary octaploid triticales, we used the *Vrn*-isogenic wheat lines Triple Dirk D, Triple Dirk B, and Triple Dirk E, carrying, respectively, only the *Vrn-A1*, *Vrn-B1*, and *Vrn-D1* genes. A comparison of a set of 8*x* triticale lines and 6*x* samples from the VIR world collection showed that the interphase period "germination–heading" of hexaploid triticales is shorter (Stepochkin, Emtseva, 2017). There is an assumption that reducing the level of ploidy can reduce the duration of the period "from germination to heading" in wheat-rye amphiploids. In particular, it was reported that within the crossing combination, octaploid lines formed ears later than hexaploid ones (Kaminskaya et al., 2005).

The hexaploid paternal variety Sears 57 (genomic formula B^{u}B^{u}AARR), has a winter type of development. All its *vrn-1* genes have recessive alleles. The maternal forms are three spring octaploid triticale lines (genomic formula B^{u}B^{u}AADDRR). Each of them carries one dominant gene: 8*xVrnA1* carries a *VrnA1a* allele on the chromosome 5A, 8*xVrnB1* contains a *VrnB1a* allele on the chromosome 5B, 8*xVrnD1* has a *Vrn-D1a* allele on the 5th chromosome of D genome. It was assumed that in 8*xVrnD1* × Sears 57 hybrids in subsequent generations, starting from F$_2$, the chromosomes of the haploid D genome would be lost during the process of meiosis, and the share of winter plants in the hybrid populations would increase. As a result, in the older generations there would be only winter hexaploid forms with the chromosome number 42 without the haploid genome D and without the dominant allele *Vrn-D1a*. The facts of complete elimination of chromosomes of D genome in such types of crossing are known (Hao et al., 2013). However, by selecting spring plants we were able to create up to the fourth generation populations of 6*x* forms that could begin transition to the generative development after spring sowing without vernalization. Molecular genetic analysis using the PCR method showed the presence of the dominant *Vrn-D1a* allele in these forms (see Fig. 3). This means that either as a result of chromosome

substitution or translocation, the *Vrn-D1* gene remained in the complex genome of hexaploid plants. Some researchers report inclusion of a genetic material of the wheat genome D in the genome of hexaploid triticale forms (Kaminskaya et al., 2005). Unlike plants of 8*xVrnD1* × Sears 57 population, hexaploid triticale forms made by crosses 8*xVrnA1* × Sears 57 and 8*xVrnB1* × Sears 57 do not contain any *Vrn-D1* allele, as it was shown by molecular analysis with primers to *Vrn-D1* gene, although the maternal lines contain a recessive *vrn-D1* allele. The lack of amplification is probably due to the elimination of chromosomes of the D genome.

It is known that octaploid triticales are cytogenetically unstable. As a result of disturbances in meiosis, gametes with an unbalanced number of chromosomes are formed, which leads to appearance of aneuploid plants in 8*x* WRA populations (Vettel, 1960a, b; Krolow, 1962, 1963). Hexaploid triticale plants with dominant *Vrn-1* genes may arise as a result of spontaneous depoliploidization of octaploid WRA carrying these genes. This process is accompanied by the predominant elimination of the chromosomes of D genome of soft wheat in octaploid WRA. At the end of this process, stable 6*x* triticales appear, which was found in populations of a number of 8*x* triticales (Stepochkin, 1978; Li et al., 2015).

Conclusion

The presented results showed that the populations of spring octaploid triticales made and maintained at SibRIPP&B – Branch of ICG SB RAS are donors of different dominant *Vrn-1* genes. These populations are used to produce new forms of 8*x* and 6*x* WRA and for breeding process. In the hexaploid triticale forms made on their basis, the allelic composition of the *Vrn-1* genes was determined using molecular genetic analysis. It was found that plants from the populations of 8*xVrnA1* × Sears 57 and 8*xVrnB1* × Sears 57 have genes *Vrn-A1* and *Vrn-B1* in a heterozygous state, so it is necessary to conduct further selection to make homozygous genotypes. In the

created hexaploid forms of triticale, the grain number from ear is higher than that in the original octaploid lines. It is shown that the plants from the hybrid populations 8*xVrnA1* × Sears 57 and 8*xVrnD1* × Sears 57, carrying the dominant alleles *Vrn-A1a* and *Vrn-D1a*, respectively, have a shorter duration of the interphase period "germination–heading" than the original parent forms of the primary 8*x* triticale, which is a breeding-valuable feature for the creation of early-maturing and productive genotypes of triticale.

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