Study of 8x and 6x triticale with dominant *Vrn* genes

P.I. Stepochkin

Siberian Research Institute for Plant Industry and Breeding – Branch of the Institute of Cytology and Genetics, SB RAS, Krasnoobsk, Novosibirsk region, Russia

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* e-mail: petstep@ngs.ru

Abstract: Secondary hexaploid (6x) triticale plants made by hybridization of a 6x winter triticale variety with octaploid (8x) triticale plants bearing the dominant *Vrn1* gene have different "shoots – earing" interphase period durations, which forms the following series: 6x*VrnD4* ≥ 6x*VrnB1* > 6x*VrnD1* ≥ 6x*VrnA1*. Plants of 8x triticale compared with 6x ones have denser spikes and a higher seed set. Plants of line 8x*VrnD4* had the longest "shoots – earing" interphase period (74.3 ± 1.7 days) among all 8x triticale studied in 2018, while *8xVrnD1* triticale plants had the shortest one (49.5 ± 2.6 days). Plants of 6x*VrnA1* triticale had the shortest "shoots-earing" interphase period (47.4 ± 0.9 days) among all 6x triticale studied. Plants of the triticale 8x*VrnD1* and 6x*VrnD1* inherited, from the wheat 'Triple Dirk E', the Ne1 and Ne2 genes that accounted for the manifestation of leaf hybrid necrosis and a low seed set. Secondary 6x triticale with the dominant *VrnA1* gene possesses the shortest "shoots – earing" interphase period and a good seed set and is used in triticale breeding programs.
Key words: octaploid; hexaploid; triticale; *Vrn* genes; interphase period.

1. Introduction

There are three levels of ploidy of a synthetic wheat-rye allopolyploid or triticale (× Triticosecale sp. Wittmack). They are tetraploid (4x), hexaploid (6x) and octaploid (8x). Although a lot of triticale varieties are of 6x level of ploidy, some octaploid triticale varieties were made in China (Zhi-Jun Cheng, Minoru Murata, 2002). According to the lifestyle and the type of plant development, there are winter, spring and winter-spring or alternative triticales. The spring- type development and the duration of the "shoots-earing" interphase are determined by dominant *Vrn* genes located on wheat chromosomes 5A, 5B and 5D (Fu et al., 2005; Yoshida et al., 2010) and on rye chromosome 5R (Plaschke et al., 1993). In this report, some results of studying 8x and 6x triticales with dominant *Vrn* genes are given and discussed.

2. Materials and methods

Triticale (Trl) of two ploidy levels was created and studied in the Siberian Research Institute of Plant Growing and Breeding, a branch of the Institute of Cytology and Genetics, SB RAS. In the octaploid (8x) triticale nursery in 2018, we studied 4 forms of primary 8x wheat-rye amphidiploids (WRA): 8x*VrnA1* (genotype *VrnA1VrnA1 vrnB1vrnB1 vrnD1vrnD1 vrnD4vrnD4*), 8x*VrnD1* (genotype *vrnA1vrnA1 vrnB1vrnB1 VrnD1VrnD1 vrnD4vrnD4*), 8x*VrnB1* (genotype *vrnA1vrnA1 VrnB1VrnB1 vrnD1vrnD1 vrnD4vrnD4*) and 8x*VrnD4* (genotype *vrnA1vrnA1 vrnB1vrnB1 vrnD1vrnD1 VrnD4VrnD4*) created by the artificial doubling of chromosome number of wheat-rye hybrids from crosses between the winter rye variety 'Korotkostebelnaya 69' (genotype *vrnR1*) and four soft wheat lines, 'Triple Dirk D', 'Triple Dirk B', 'Triple Dirk E' and 'Triple Dirk F' as donors of four different dominant genes, *Vrn – Vrn A1, Vrn B1, Vrn D1* and *Vrn D4*, correspondently (Stepochkin, 2009). In the nursery of hexaploid (6x) triticale, we studied F_6 hybrids obtained from crosses, in 2014, between four primary octaploid triticale (8x*VrnA1*, 8x*VrnD1*, 8x*VrnB1* and 8x*VrnD4*) and the winter hexaploid triticale 'Sirs 57' (6x winter Trl) bearing recessive *vrn* genes. In this nursery, we also studied the 6x triticale forms 6x*VrnA1*, 6x*VrnB1*, 6x*VrnD1* and 6x*VrnD4* derived from the populations of 8x triticale with dominant *Vrn* genes. During the vegetation period from shooting to ripening, we carried out phenological observations. Qualitative and quantitative traits were studied.

3. Results and discussion

Spikes of 6x triticale morphologically differ from those of 8x triticale and are close to those in rye (Figure 1).

Their ears are denser than those of the original 8x WRA and their seed set is almost two times higher than that of 8x triticale (Table 1). For these traits, the hexaploid triticale plants of both groups do not differ significantly from each other except for 6x *VrnD1*. Plants of this WRA, as well as those of the F_6 hybrid (8x*VrnD1* × 6x winter Trl) and the octaploid WRA 8x*VrnD1* have two qualitative traits, leaf necrosis and hairy glumes, inherited from the initial wheat line 'Triple Dirk E', the maternal parental form and the donor of the dominant *VrnD1* gene for producing the 8x *VrnD1* triticale (Stepochkin, 2009). Leaf necrosis, perhaps, led to the low seed set in the spikes of plants of the WRA made on the basis the wheat line 'Triple Dirk E'. It is known that a hybrid leaf necrosis caused by a complementary action of the Ne_1 and Ne_2 genes leads to grain production problems in wheats developed by interspecies crosses or crosses between a winter and a spring variety (Hermsen, 1963). The wheat line 'Triple Dirk E' is of hybrid origin (Goncharov, 2012).

Triticale plants bearing the dominant *VrnA1* or *VrnD1* gene have a shorter "shoots – earing" interphase period than those that bear the dominant *VrnB1* or *VrnD4* gene. The plants that have the dominant *VrnD4* gene show the longest duration of this period. Both the hexaploid triticale and the primary octaploid triticale plants bearing the dominant *Vrn* gene have "shoots – earing" interphase period duration that forms the following series: Trl *VrnD4*≥ Trl *VrnB1* > Trl *VrnD1*≥ Trl *VrnA1*. Plants of line 8x*VrnD4* had the longest "shoots – earing" period (74.3 ± 1.7 days) among all 8x triticale studied, while 8x*VrnD1* triticale plants had the shortest one (49.5 ± 2.6

Figure 1. Spikes of common wheat 'Triple Dirk D' (*a*), winter rye 'Korotkostebelnaya' (*b*), 8x triticale 8x*VrnA1* (*c*) and 6x triticale 6x*VrnA1*.

Table 1
Duration of the "shoots – earing" period, spike density and spike grain number of 8x and 6x triticales with dominant *Vrn* genes

Names of triticale	Duration of the "shoots – earing" period, days	Spike density, number of spikelets / length of spike	Spike grain number
8xVrnA1	51.0 ± 1.8	1.89 ± 0.02	22.5 ± 0.6
8xVrnD1	49.5 ± 2.6	1.74 ± 0.03	7.8* ± 1.3
8xVrnB1	71.2 ± 4.3	1.87 ± 0.03	12.3 ± 1.1
8xVrnD4	74.3* ± 1.7	1.85 ± 0.02	11.0 ± 0.7
8xVrnA1 × 6x winter Trl	45.1 ± 2.5	2.93 ± 0.05	38.9 ± 3.0
8xVrnD1 × 6x winter Trl	55.2 ± 6.7	2.98 ± 0.06	27.4* ± 2.7
8xVrnB1 × 6x winter Trl	56.4 ± 2.1	2.97 ± 0.06	42.9 ± 1.7
8xVrnD4 × 6x winter Trl	67.0 ± 5.2	2.85 ± 0.13	42.0 ± 3.6
6xVrnA1	47.4 ± 0.9	3.00 ± 0.06	38.0 ± 2.6
6xVrnD1	49.2 ± 0.6	3.17* ± 0.04	28.0* ± 1.5
6xVrnB1	58.9 ± 0.4	2.95 ± 0.04	35.0 ± 1.6
6xVrnD4	70.8* ± 0.7	2.90 ± 0.06	42.8 ± 2.7

* Significant difference at $p < 0.05$.

days). Hexaploid triticales derived from octaploid WRA populations as a result of spontaneous depolyploidization and elimination of 14 chromosomes of the D genome (Stepochkin, 1978; Zhi-Jun Cheng, Minoru Murata, 2002; Li et al., 2015). They are of breeding interest. Plants of 6x*VrnA1* triticale had the shortest "shoots–earing" interphase period (47.4 ± 0.9 days) among all 6x triticale studied. The F_6 hybrid lines from cross of 8x*VrnA1* × 6x winter triticale showed the shortest "shoots–earing" interphase period and a good seed set among all triticales studied, which also makes it promising for further breeding programs.

4. Conclusions

The results of the study of two-level ploidy triticales showed that the secondary hexaploid triticale plants made by hybridization of a 6x winter triticale variety with octaploid triticale plants bearing the dominant *Vrn1* gene have different "shoots–earing" interphase period durations and form the following series: 6x*VrnD4* ≥ 6x*VrnB1* > 6x*VrnD1* ≥ 6x*VrnA1*. Plants of 8x triticale compared with 6x ones have denser spikes and a higher seed set. Plants of line 8x*VrnD4* had the longest "shoots–earing" period (74.3 ± 1.7 days) among all 8x triticale studied in 2018, while 8x*VrnD1* triticale plants had the shortest one (49.5 ± 2.6 days). Plants of 6x*VrnA1* triticale derived from the population of 8x triticale as a result of spontaneous depolyploidization and elimination of D-genome chromosomes had the shortest "shoots–earing" interphase period (47.4 ± 0.9 days) among all 6x triticale studied. 8x*VrnD1* and 6x*VrnD1* triticale plants inherited the Ne_1 and Ne_2 genes from the wheat 'Triple Dirk E', which accounted for the manifestation of leaf hybrid necrosis and a low seed set. As the secondary 6x triticale with the dominant *VrnA1* gene combines the shortest "shoots–earing" interphase period and a good seed set, it is used in triticale breeding programs.

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