On the issue of winter triticale selection improvement in the Central region non-Black Earth area conditions

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Abstract. In the conditions of the Moscow region, in 1993-2020, more than 1.0 thousand Triticale Wittmack cultivars were studied, including new varieties and lines, by using diallel crossings (DIAC) \((5 \times 5)\) and other field and laboratory experiments. Tests of varietal samples in DIAC in 2011-2012 using the method of Hayman (1954) showed that the traits of winter triticale are characterized by an additive-dominant inheritance scheme. The dominant genes made the main contribution to the increase in productivity traits, and the prospects of a particular cross-breeding combination depended on their concentration. In the competitive test (CSI) in 2015-2020, the best productivity was found in the Gera variety - 8.15 t/ha (the standard one is 7.29 t/ha). It is shown that over the past 25 years in the Federal Research Center “Nemchinovka” created more than 25 varieties of winter triticale, 12 varieties submitted to the State Register, 6 varieties are now in production, including variety Nina, released in 2013 for the Central region and combines with Samara Research Institute of Agriculture variety Capella, made to the State Register from 2019.

1. Introduction

The triticale crop is becoming more widespread around the world. According to FAOSTAT 2020, the sowing area is more than 3.8 million hectares at present. Poland accounts for 1 million 352 thousand hectares (32.5%) according to 2017 data. In Russia triticale (mainly winter one) is cultivated on the area of 300 thousand ha with the yield above 3 t/ha [1, 2].

Due to the creation and implementation of new varieties, the yield of winter triticale increases over the years and reaches a maximum of 12 t/ha [2]. At the same time, triticale also has serious disadvantages, in particular, the germination of grain onto the root, an increased susceptibility of plants to snow mold and Septoria, a weak resistance to overheating. In general, winter triticale belongs to the middle and late-maturing crops. Nina and Capella are new varieties developed at Federal Research Center “Nemchinovka” (FRC “Nemchinovka”) which have a few flaws in comparison with the standard ones. Nina variety is a precocious genotype (matures 3-5 days earlier than the Viktor standard); its plants are 10-15 cm lower than the standard one. However, the plant-breeding development of winter triticale process should be strengthened and improved. Highly productive, precocious and non-dropping varieties are of demand for production.
2. Materials and methods

The research was carried out at the FRC “Nemchinovka”. The observations and records were conducted according to the guidelines of Dospekhov [3], the state Commission for testing and protection of breeding achievements [4], the Federal Research Center All-Russian Institute of Plant Genetic Resources named after N. I. Vavilov (Saint Petersburg) [5] and other methodological manuals. A significant variability of the weather factors was noted during the years of experiments, most part of the fall seasons had lack of precipitation before and after sowing [6, 7]. There were repeated snowfalls and snowmelts at the thaw during the winter seasons. There was a lack of warm temperatures and heavy precipitation during the spring seasons of 1915, 1917, 1918, 1919, 2019, 2020. The heat deficit was more prevalent in spring (May) and summer (June) seasons of 2017, 2019 and 2020. The soil of the experimental plots is sod-podzolic with a humus content of 2.0-2.5%. The pH of the soil solution is 4.5-5.5. When cultivating triticale, fertilizers were applied (200-350 kg/ha of azophoska). Sowing was carried out with a SK-10 seeder with a seeding rate of 5 million germinating seeds per ha. The allotments area in the competitive variety trial (CVT) was 12-15 m² and the process of four-fold repetition of variants in the control nursery 3-4 m², and in the collection and hybrid nurseries - 1-2 m² was applied. As a crops nutrition 150 kg/ha of ammonium nitrate was used in the spring season [8, 9].

Quality indicators of grain, flour, dough and bread were determined according to the scheme of complete technological analysis (the number of drops according to Hagbert-Perten, the State Standard 27676-88; the amount of gluten in flour - with manual washing according to the State Standard 514/2-99, ISO 7495-90, the quality of gluten in flour was set via the IDK-4 (measurer of gluten deformation device).

3. Results and discussion

As the research result, genotypes that are valuable for a number of characteristics were identified; many of them were used in crossings. It is determined that the increased suitability for plant-breeding purposes is represented by the assortment of the Federal Research Center “Nemchinovka” (Viktor, Hermes, Nemchinovsky 56, Nina), as well as the P.P Lukyanenko National Center of Grain (NCG): Valentin 90, Swat, Brut, Knyaz, Tit; of the Federal Rostov Agricultural Research Center: Zimogor, Hector, Vocaliz; Poland (Dagro, Grenado, Presto); of the Republic of Belarus (Consul, Maara, Module, Amule); of Ukraine (Amphidiploid 10, Bouquet, K-4097).

Table 1 shows the triticale varieties and ranges selected in 2017-2020. The varieties Doctrine 110, Efremovskaya, Preco/Kill/Rex AOS; Markiyans, Topaz, Nemchinovsky 56 were noted to have the highest yield capacity and stress resistance. The polish variety Hortence (k-4012) was revealed to have a yield capacity of 900 g per 1 m².

The searching process for best samples of yield capacity and dropping resistance was conducted in the FRC “Nemchinovka”. Genotypes with the resistance to dropping and a straw length of 85-90 cm were identified, mainly these are samples from the South of Russia and from Poland.

An important trait of the triticale mentioned below is the increased capacity for spring tillering of plants, which increases grain harvest. The varieties Legion, Tribun, Skolot, Aztec, Knyaz, Brat are of a special interest for plant-breeding. Despite the lack of overwintering, the susceptibility of plants to snow mold, these triticale varieties are widely used in crosses at the Federal Research Center «Nemchinovka».

Table 2 shows triticale having a high content of protein and starch in the grain during the contrasting weather factors years (2016, 2019). High grain protein content was demonstrated by the Krasnodar Dozor variety (16.5%), Dagestani Prag 565 (18.5%), Moldovan Jngen 35 (16.2%), and Moscow Gera (17.2%). The Polish varieties Preco/Kill/Rex/AOS/Rex, Preco/Kill/AOS/Rex (13.5-15.0% of protein and 55.2-55.9% of starch) with their grain quality are supposed to be appealing.

The crop traits inheritance and triticale grain quality within diallel crossings (DIAC) (5 × 5) were assessed at the FRC “Nemchinovka”. The experiments used short-stemmed Prag 468, ADK 1369t ranges, Nina, Nemchinovsky 56 varieties and range 6418-145. DIAC materials processed according to the guidelines of Hayman (1954), Mather and Ginks (1971) using AGROS 2009 programs which
allowed to determine inheritance and genetic control of a number of traits. In the field and laboratory experiments with the determination of indicators characterizing varieties and hybrids participation, as well as genetic variances obtained from the analysis of diallel crossings (5 × 5), the h/D ratio reflecting the average level of dominance for polymorphic loci, the values (H1(D) 1/2 characterizing the average degree of dominance, the execution of regression graphs \( W_r \) on \( V_t \) with the calculation of the correlation coefficient, it was found that for all the studied traits, the dominant inheritance scheme is characteristic. According to the 1000-grains mass and the protein content in the grain in the first generation of hybrids, overdomination was revealed. By the weight of the grain per a spike, the nature of the study varied from complete dominance to overdomination.

On 1000-grains mass basis, the line Prag 468 had the advantage, on the mass of grain from the spike basis- the line ADK 1369t. The high starch content in the grain was attributed to the dominant action of genes, and the Prag 418 and 6418-145 ranges were particularly notable.

The analysis of the general and specific combination ability (GCA and SCA) showed that genes with dominant effects have a predominant influence in the inheritance of a 1000- grains mass trait. In the genetic variance of this trait, the proportion of SCA variation was 52.8%, which is 1.5 times higher than the variation of GCA (37.3%). A consistently high rate of GCA was detected only for Nina variety. According to the SCA, combinations of Prag 468 x 6418-145 and ADK 1369t × Nemchinovsky 56 were distinguished. In the genetic variance of the grain-weight-per-spike trait, the share of variants of GCA was 59.2% (SCA-33.6%) on average over two years. These data suggest that the most significant contribution to the genotypic variation is made by the additive effects of genes, Prag 468, 6418-145; and Nina variety showed positive results for GCA. It is likely that Prag 468 range as a donor is equally stable at transmission of its trait to all hybrids, this was also proved by the high GCA and low SCA variant.

The selection process at the FRC “Nemchinovka” resulted in the creation of the 12 varieties most common in the production - Nemchinovsky 56, Nina and Capella varieties, which also were presented for the state registration. New varieties and ranges, which are complete comparing to the standard ones, with a potential yield of more than 13 t/ha, obtained by crossing local genotypes with the best samples of the world collection, are tested at the experimental sites of the FRC “Nemchinovka”. Breeding achievements of the FRC “Nemchinovka” are based on a new extensive initial material, significant amounts of breeding work. The actual grain harvest of specific varieties reached 12 t/ha in 2014-2020 (Table 3).

Table 4 demonstrates indicators of grain technological properties within the contrasting weather factors of 2017 and 2019. According to the content of protein and gluten in the grain (20.2 and 23.4%), the Nemchinovsky 56 variety was distinguished. However, it has a low overall output of bread (in 2017 -495 cm³, in 2019 - 360 cm³). The Gera variety seemed appealing in a number of ways (15.6 and 17.2% protein; 21.0 and 19.8% gluten). In 2017, the Gera variety surpassed other varieties and ranges (610 cm³ and 490 cm³) in the volume output of bread. The standard Victor’s indicators were 490 and 460 cm³, respectively.
### Table 1. Winter triticale varieties that were distinguished in 2017-2020, according to the set of characteristics.

| №  | Variety samples ranges                               | Plant height, cm | Over wintering score | Resistance to snow mold, score | Grain quantity per spike, pcs | Grain mass per spike, g | 1000 - grain weight, g | Grain harvest g/m² | 2017 | 2018 | 2019 | 2020 |
|----|------------------------------------------------------|------------------|----------------------|--------------------------------|-------------------------------|------------------------|------------------------|---------------------|------|------|------|------|
| 1  | St1 Hermes, FRC “Nemchinovka”                        | 110              | 7                    | 5                              | 51                            | 2.8                    | 60.0                   | 370                 | 600 | 800 | 720 |
| 2  | St2 Victor FRC “Nemchinovka”                         | 105              | 7                    | 9                              | 52                            | 3.0                    | 59.2                   | 800                 | 610 | 780 | 695 |
| 3  | Doctrina 110, The Research Institute of Science in Agriculture, Voronezh Efremovskaya, MOVIR (Federal Horticultural Research Center for breeding, agrotechnology and nursery) | 115              | 9                    | 5                              | 55                            | 3.0                    | 58.0                   | 840                 | 550 | 850 | 600 |
| 4  | Felo (K-4010), Poland                               | 105              | 9                    | 5                              | 53                            | 3.2                    | 61.4                   | 590                 | 675 | 790 | 670 |
| 5  | Hortence (K-4012), Poland                           | 95               | 9                    | 7                              | 53                            | 2.8                    | 61.6                   | -                   | -   | 890 | 750 |
| 6  | Preco(Kill) |Rex|AOS, Poland                                               | 92               | 7                    | 5                              | 56                            | 3.1                    | 56.0                   | 860                 | 800 | 860 | 572 |
| 7  | Amulet (K-3950), Belarus                            | 110              | 7                    | 5                              | 54                            | 3.2                    | 54.0                   | -                   | -   | 850 | 780 |
| 8  | Markiyan (K-4098), Ukraine                          | 90               | 9                    | 9                              | 55                            | 2.8                    | 55.0                   | -                   | -   | 850 | 520 |
| 9  | Topaz. The Federal Center of Science in Agriculture, Rostov Nemchinovskiy 56 FRC “Nemchinovka” | 92               | 7                    | 5                              | 60                            | 3.0                    | 57.2                   | 450                 | 570 | 820 | 615 |
| 16 | The least significant difference 0.05               | 105              | 7                    | 7                              | 56                            | 3.1                    | 58.0                   | 720                 | 620 | 820 | 680 |

The least significant difference 0.05
Table 2. White triticale varieties with a high content of protein and starch in the grain, Federal Research Center “Nemchinovka" 2016, 2019.

| №   | Variety, number of VIR* catalogue | Origin | Content of protein in the grain, % | Content of starch in the grain, % |
|-----|----------------------------------|--------|-----------------------------------|-----------------------------------|
|     |                                  |        | 2016 | 2019 | Average in 2 years | 2016 | 2019 | Average in 2 years |
| 1   | Hermes, St1                      | FRC “Nemchinovka” | 16.2 | 13 | 14.6 | 57.6 | 57 | 57.3 |
| 2   | Victor, St2                      | FRC “Nemchinovka” | 12.9 | 13.3 | 13.1 | 51.8 | 56.6 | 54.2 |
| 3   | Efremovskaya                     | MOVIR (the Federal Horticultural Research Center for breeding, agrotechnology and nursery) | 15.4 | 14.6 | 15 | 55.7 | 57.2 | 56.5 |
| 4   | White wheat Moskovskaya 39      | FRC “Nemchinovka” | 15.3 | 14.7 | 15 | 62.5 | 54 | 58.2 |
| 5   | Preco/Kill/Rex/Aos/Rex          | Poland | 13.9 | 13.1 | 13.5 | 56.6 | 53.8 | 55.2 |
| 6   | Preco/Kill/Aos/Rex              | Poland | 15.1 | 14.9 | 15 | 56.5 | 54.3 | 55.4 |
| 7   | Ambraz/Yvan/Rex                 | Poland | 14.0 | 14.7 | 14.4 | 56.1 | 55.6 | 55.9 |
| 8   | Roma                             | Poland, K-4007 | - | 13.4 | - | 57.4 | - | - |
| 9   | Grenado                          | Poland, K-4011 | - | 12.7 | - | - | 53.4 | - |
| 10  | Dozor                            | The Research Institute of Science in Agriculture, Krasnodar K-4021 | 13.6 | 16.5 | 15.1 | 53.1 | 57.8 | 55.5 |
| 11  | Don                              | The Federal Center of Science in Agriculture, Rostov | 15.8 | - | - | 58 | - | - |
| 12  | Prag 565, k-4111                 | Dagestan experimental station of VIR | - | 18.5 | - | 46.7 | - | - |
| 13  | Zhitsen                          | Belarus | 13.8 | 15.1 | 14.5 | 54.7 | 52.6 | 53.7 |
| 14  | Ingen 35                         | Moldova, K-4101 | - | 16.2 | - | 61.9 | - | - |
| 15  | Nemchinovskiy 56                 | FRC “Nemchinovka” | 14.6 | 13.6 | 14.1 | 52.8 | 55.2 | 54.0 |
| 16  | Gera                             | FRC “Nemchinovka” | 16.5 | 17.2 | 16.8 | 58.2 | 55.8 | 57.0 |
| 17  | Topaz                            | The Federal Center of Science in Agriculture, Rostov | 13.2 | 13.0 | 13.1 | 49.6 | 55.4 | 52.5 |

*The Federal Research Center All-Russian Institute of Plant Genetic Resources named after N.I. Vavilov (Saint Petersburg).
3. Yield capacity (t/ha) of the best varieties and ranges within CVT of the FRC “Nemchinovka” in 2014-2019.

| Variety, range     | 2014 | 2015 | 2016 | 2017 | 2018 | 2019 | Average in 6 years |
|--------------------|------|------|------|------|------|------|-------------------|
| Victor, St         | 6.90 | 9.3  | 6.17 | 8.9  | 5.70 | 6.40 | 7.23             |
| Hermes             | 6.98 | 10.72| 5.47 | 7.24 | 6.11 | 7.30 |                  |
| Nemchinovskiy 56   | 8.12 | 8.86 | 6.63 | 7.63 | 6.71 | 7.59 |                  |
| Nina               | 7.40 | 9.65 | 6.78 | 7.38 | 6.66 | 8.0  |                  |
| Gera (121-1-9)     | 9.51 | 11.34| 7.49 | 7.64 | 7.70 | 6.96 | 8.38             |
| 6355-26-2-26       | 7.11 | 8.46 | 8.75 | 7.28 |      |      | 8.26             |
| 150-1-5            | 6.95 | 9.48 | 8.35 |      |      |      | 8.26             |
| The least significant difference 05 | 0.35 | 0.57 | 0.51 | 0.45 | 1.13 | 0.84 |                  |

4. Conclusion
The study of the global gene pool of winter triticale resulted in the identification of genotypes that differ in a complex of valuable traits, which involvement in crossing with local samples of triticale provided a new promising assortment with increased indicators of quality, yield and resistance to stress. The new Capella variety was obtained based on the breeding with the Polish spring triticale variety (K-2045) with the use of ecological mutagenesis and subsequent crosses. The FRC "Nemchinovka" received extensive breeding material, including ranges and varieties with the potential productivity of more than 13 t/ha, increased adaptability to the conditions of the Central non-black earth regions. The Arcturus variety especially excels among them, as well as ranges 618-116 and...
6408-19-71. The Arcturus variety, obtained during complex crosses of local genotypes with the short-stemmed Avangard variety in the Moscow region, provides a high-quality grain harvest of more than 12 t/ha. The short-stemmed variety Arcturus has been under the State Variety Testing since 2019.

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