Screening economically important features of spring common wheat varieties of CIMMYT breeding in the central Russia

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Abstract. Creating of populations with wide genotypic diversity is the basis of successful selection of promising lines. This can be achieved by involving breeding material from various ecological and geographical origins, as well as interspecific hybrids, in crossing. 14 spring common wheat (Triticum aestivum L.) varieties of CIMMYT breeding (Mexico) were researched to identify the genetic sources of economically important features. A number of these varieties proved to be the sources of adaptability to biotic and abiotic stresses and high grain quality. The yield properties of the Mexican varieties in the central Russia were at or below the standard – the ‘Zlata’ wheat variety.

1. Introduction

The State Commission for Selection Achievements Test and Protection of the Russian Federation focuses mainly on the yields of new testing varieties. Unfortunately, high quality wheat grain requires additional investments, which are often not paying off [1]. The known negative correlation between yield and quality has led to the expansion of high-yielding varieties with low grain quality. As a result, during bread and bakery goods production the technologists have to use artificial improvers of baking properties of low-quality flour with mild gluten. The rise in allergic reactions necessitates crop breeders creating competitive, adaptive varieties of common wheat with high yield rate and good grain quality.

Spring common wheat (Triticum aestivum L.) best meets the specified criteria for yield and grain quality [2]. It exceeds the winter wheat in bakery qualities, does not depend from winter conditions, and also is able to give high yield in terms of proper care. The ecological-geographical criterion is one of the principles of pair selection for crossing and creation of diverse populations for selection. Involving in the hybridization the wheat genotypes from world collection, such as CIMMYT germplasm, allows us to create varieties with complex resistance to pathogens [3]. The International Maize and Wheat Improvement Center (CIMMYT, Mexico) is actively working to improve the baking qualities of spring wheat grain, to create synthetic wheat etc. Genotypes that have in the pedigree Aegilops tauschii (syn. Ae. squarrosa) are more various genetically, which makes them promising for creating populations for selection. In addition, such genotypes are more resistant to various abiotic and biotic stresses [4]. 14 spring common wheat varieties of CIMMYT breeding (Mexico) were researched to identify the genetic sources of economically important features.
2. Materials and methods
Investigations were conducted at the Russian State Agrarian University – Moscow Timiryazev Agricultural Academy. The field trials were carried out at the Field Experimental Station, laboratory analyzes – at the Department of Genetics, Plant Breeding and Seed Production.

The material were obtained from the International Maize and Wheat Improvement Center (CIMMYT, Mexico) (table 1).The standard – spring common wheat variety Zlata was breeded by the Federal Research Center “Nemchinovka” & Upper Volga Federal Agrarian Scientific Center. It should be noted that the genealogies of the samples 6, 13, 87, and 107 contain the species Aegilops squarrosa, and the species Triticum dicoccum participated in creating the sample 107.

Table 1. Pedigree of the genotypes according to the CIMMYT catalog

| Sample number by the CIMMYT catalog | Pedigree |
|-------------------------------------|----------|
| No. 1 AC SPLENDOR/4/SNI/TRAP#1/3/KAUZ*2/TRA//KAUZ |
| No. 6 LONG92-1640/4/SLVS/3/CROC_1/AE.SQUARROSA (224)///OPATA |
| No. 13 ERNEST/3/CROC_1/AE.SQUARROSA (205)///KAUZ |
| No. 24 GLE*2//PBW343*2/TUKURU |
| No. 41 SD 3355/4/MILAN/KAUZ//PRINIA/3/BAV92 |
| No. 46 GLE*2/ROLFO7 |
| No. 48 KEHAN 8/3/WEAVER/PLATA_3//2*BORL95/4/LONG CHUN 13 |
| No. 85 TERTSIA/7/TOB/ERA//TOB/CNO673/PLO/4/VEE#5/KAUZ/6/FRET2 |
| No. 87 FORA/4/PARUS/3/CHEN/AE.SQ.//2*OPATA |
| No. 92 CHELYABA/3/PASTOR//HXL753//2*BAU |
| No. 107 LUTESCENS 30-94/3/T.DICOCCON P94625/AE.SQUARROSA (372)///3*PASTOR |
| No. 153 LUTESCENS 1085/7/TOB/ERA//TOB/CNO67/3/PLO/4/VEE#5/KAUZ/6/FRET2 |
| No. 178 OMSKAYA 37/5/SERI*3//RL6010/4*YR/3/PASTOR/4/BAV92 |
| No. 214 LUTESCENS-13,KAZ/2//LUTESCENS 30-94 |

Cultural practices were common for the central Russia. Plot area was 1 m², layout – randomized complete block design with 3 replications. Lodging resistance was determined by the method of state variety testing on a 5-point scale, where 1 corresponds to complete lodging, 5 indicates the absence of lodging. Resistance to fungal diseases was determined using a 9-point VIR scale: 1 – very severe damage (susceptibility to disease), 9 – no damage (resistance).

Laboratory assessments were carried out by the following methods: the mass of 1000 seeds was calculated by the accelerated method, the grain-unit was determined by the micromethod, the vitreousness – with a diaphanoscope, the protein percentage – with a “Spectran IT” spectrophotometer. Statistical processing was performed by one-way analysis of variance. The final assessment of the variety samples was carried out by the index method [5].

The meteorological conditions of the growing season in 2020 made it possible to assess the potential of the studied genotypes of spring wheat (Fig. 1). Favorable conditions of early and mid-May contributed to the amicable emergence of seedlings and good tillering. A further excess of precipitation at moderate and elevated temperatures led to a powerful development of the vegetative mass, grain size, the development of lodging and fungal diseases. Excess precipitation against the background of low temperatures accompanied the beginning of wheat grain ripening (third decade of July), dry temperate weather (first decade of August) – the end of maturation.
3. Results and discussion

Since in the Mexico there is no necessity to reduce the growth duration as in the Central regions of the Non-chernozem zone, among the studied samples, only 7 were early maturing. Genotypes 1, 6, and 48 ripened at the same time as the early maturing standard Zlata - on August 5. Genotypes 92, 107, 178, and 214 matured 2-3 days, No. 85 - 5 days later. In the rest of the samples, full maturity began only on August 16.

Approximately half of the studied genotypes exceeded the standard height, they reached 115-125 cm, but, despite this, they were characterized by high resistance to lodging (5 points) (Table 2).

Table 2. Yield, height and diseases resistant of the studied wheat genotypes

| The number by the CIMMYT catalog | Yield, g/m² | percentage of the standard | Plant height, cm | Score of resistance to lodging | leaf rust | powdery mildew | fusarium spike blight |
|----------------------------------|-------------|---------------------------|-----------------|-------------------------------|----------|----------------|----------------------|
| Zlata (st)                       | 615.5       | 100                       | 110             | 5                             | 7        | 7              | 5                    |
| No. 1                            | 565.2       | 92                        | 110             | 5                             | 9        | 9              | 9                    |
| No. 6                            | 474.7       | 77                        | 105             | 5                             | 9        | 7              | 3                    |
| No. 13                           | 505.9       | 82                        | 120             | 5                             | 9        | 7              | 3                    |
| No. 24                           | 514.9       | 84                        | 110             | 5                             | 9        | 9              | 3                    |
| No. 41                           | 729.1       | 118                       | 125             | 5                             | 9        | 9              | 3                    |
| No. 46                           | 644.1       | 105                       | 115             | 5                             | 9        | 9              | 3                    |
| No. 48                           | 513.1       | 83                        | 95              | 5                             | 9        | 9              | 3                    |
| No. 85                           | 585.1       | 95                        | 105             | 5                             | 9        | 9              | 3                    |
| No. 87                           | 515.3       | 84                        | 110             | 5                             | 9        | 9              | 3                    |
| No. 92                           | 466.4       | 76                        | 115             | 5                             | 7        | 9              | 5                    |
| No. 107                          | 455.0       | 74                        | 115             | 5                             | 9        | 9              | 5                    |
| No. 153                          | 703.2       | 114                       | 125             | 5                             | 9        | 9              | 3                    |
| No. 178                          | 525.7       | 85                        | 125             | 5                             | 9        | 9              | 3                    |
| No. 214                          | 483.3       | 79                        | 115             | 5                             | 9        | 9              | 3                    |
| LSD₈₅                            | 137.6       | –                         | –               | –                             | –        | –              | –                    |
Only sample no. 87 was strongly lodged, although the plants did not exceed the standard in height. In this way in the presented samples, the decisive indicator of lodging resistance is the stem strength. Also, low-growing varieties were selected: 6, 48 and 85 with height of stem 105, 95 and 105 cm respectively.

Resistance to leaf rust (*Puccinia recondita*), powdery mildew (*Erysiphe graminis*) and fusarium spike blight (*Fusarium sp.*) are essential in the overwetting zone. In 2020, a fairly strong development of pathogenic microorganisms was observed due to excess moisture and high air temperature. All varieties of Mexican collection proved to be resistant to leaf rust races widespread in the Central part of Russia (table 2). The sources of resistance to powdery mildew are varieties no. 13 and *Zlata*. Half of the varieties showed signs of fusarium infection, including the standard one. The average degree of resistance to fusarium was observed in varieties 6, 46, 48, 87, 92 and *Zlata*. It was registered the loose smut lesion at the sample no. 178. Variants 41 and 46 were characterized by resistance to *Septoria*. It is necessary to distinguish genotypes 1, 24, 41, 107 and 214, which have a complex resistance to lodging and basic fungal diseases.

Productivity is an integral indicator of a variety's adaptability. Although the conditions of 2020 contributed to develop the yield potential, the varieties of Mexican breeding were below the *Zlata* standard or were at its level. Samples with significantly higher yields were not found. The maximum yield was observed in samples 41, 46 and 153: their yield was 105–118% to the standard, the minimum – in samples 6, 92 and 107. Moreover, the latter were significantly less productive than the standard.

One of the main indicators of wheat grain quality is the protein content (table 3). Indirect indicators of the flour-milling and baking qualities of grain are also its physical properties: the mass of 1000 seeds, grain-unit and general vitreousness. The studied varieties showed a positive correlation between the grain yield and the weight of 1000 seeds, as well as a negative dependence between the yield and the protein content (fig. 2).

The weight of 1000 grains is determined by grain size and its plumpness. Varieties 1, 24, 41, 46, 85, 92 and 153 were significantly higher than the standard for this character, three of which (1, 24, 41) had complex resistance to lodging and fungal pathogens (table 3). The plumpness of grain is also defined by its grain-unit. Samples 6, 13, 24, 46, 48, 85 and 178 had a grain-unit significantly higher than *Zlata*, three of them (24, 46, 85) also had high weight index of 1000 grains. Despite the fact that the general vitreousness of grain is a genetically determined feature in soft wheat, its intensity is strongly influenced by the meteorological conditions of a particular year. In half of the varieties, the endosperm was average-mealy. A number of samples formed a highly vitreous endosperm, which indirectly indicates flour with good baking properties (6, 46, 48, 87, 92, 107, 153).
Table 3. Grain quality indicators of Mexican varieties of spring wheat

| Variety | 1000-grain weight, g | Grain-unit, g/l | General vitreousness, % | Protein content, % | Complex index of breeding value |
|---------|----------------------|-----------------|-------------------------|-------------------|--------------------------------|
| Zlata (st) | 42.6                | 785             | 50.8                    | 12.6              | 0.405                           |
| No. 1    | 49.8                | 767             | 62.2                    | 12.5              | 1.524                           |
| No. 6    | 42.0                | 810             | 80                      | 12.3              | 0.768                           |
| No. 13   | 41.5                | 822             | 60                      | 12.5              | 0.334                           |
| No. 24   | 45.7                | 813             | 60.8                    | 12                | 1.276                           |
| No. 41   | 47.1                | 808             | 61.8                    | 10.2              | 1.817                           |
| No. 46   | 49.9                | 810             | 97.5                    | 11.6              | 1.566                           |
| No. 48   | 43.4                | 823             | 85                      | 11.6              | 0.790                           |
| No. 85   | 46.5                | 816             | 51.2                    | 11.3              | 0.618                           |
| No. 87   | 36.8                | 750             | 94.7                    | 13.8              | 0.210                           |
| No. 92   | 47.7                | 800             | 88.8                    | 12.4              | 0.808                           |
| No. 107  | 43.8                | 798             | 70                      | 12.5              | 1.325                           |
| No. 153  | 45.9                | 795             | 75.7                    | 11.4              | 1.279                           |
| No. 178  | 43.1                | 812             | 57                      | 10.3              | 1.118                           |
| No. 214  | 43.5                | 809             | 67.2                    | 11.4              | 1.237                           |
| LSD05    | 2.8                 | 24              | 17                      | 0.3               | —                               |

The diversity of the studied varieties is noted for a number of technological and economic characteristics. In order to simplify the task and select among the set of samples only those that will satisfy the manufacturer's needs as much as possible, the index method is used. Separate indexes were calculated for each sample. We used the index \( I = \frac{\text{indicator value of the variety}}{\text{arithmetic mean value of the indicator by all varieties}} \). Then the complex indexes for each variety were calculated by multiplying the separate indexes. The higher the obtained product, the better the wheat variety according to the complex of characteristics.

To calculate the complex indexes, the values of the following characteristics were used: yield, resistance to lodging, leaf rust, powdery mildew, fusarium spike blight, weight of 1000 grains, grain-unit, vitreousness, protein content (tab. 2,3). In the course of the index evaluation, it was possible to identify varieties which index value was close to or higher than the standard value – 1, 24, 41, 46, 107, 153 and 178. It is these samples that should be used in the spring wheat breeding for product quality, since they have good yield indicators and excellent indirect indicators of flour-milling and baking qualities.

4. Conclusions

All varieties of spring common wheat by CIMMYT breeding, except no. 87, have strong stems and are sources of resistance to lodging. Samples numbered 1, 24, 41, 107, 178 and 214 have a complex resistance to lodging and to the main fungal diseases in the Central zone of the European part of Russia. All varieties of Mexican origin were found to be unsuitable for selection for higher yields. By the protein content, sample no. 87 was found to be the most valuable in quality. Varieties 1, 24, 41, 46, 107, 153 and 178 had the highest values of the complex indices. It is these samples that are recommended to be included in breeding programs, since they have good yields along with high quality indicators.

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