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ИЗУЧЕНИЕ ИСХОДНОГО МАТЕРИАЛА ОЗИМОЙ МЯГКОЙ ПШЕНИЦЫ ДЛЯ СЕЛЕКЦИИ НА КАЧЕСТВО ЗЕРНА

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Представлены источники ценных признаков для целенаправленного использования в селекции новых сортов озимой пшеницы с улучшенными признаками качества. Приведены результаты оценки исходного материала по выраженности хозяйственно ценных признаков у коллекционных образцов озимой мягкой пшеницы. В работе представлены данные по 31 сорту различного эколого-географического происхождения. Полевые опыты проводили в 2018–2020 гг. в селекционном севообороте в условиях южной зоны Ростовской области. Показатели качества сортов: массу 1000 зерен, содержание белка, количество и качество клейковины в зерне, натуру зерна, общую стекловидность, хлебопекарные свойства – определяли по стандартным методикам и ГОСТам. В результате проведенной кластеризации сортов показано, что селекционная программа по созданию адаптивных сортов с высоким качеством зерна должна включать в качестве базового исходного материала сорта, входящие в 5-й и 6-й кластеры, – Л-19578 (Россия), Этана (Германия), Warwick (Канада), Akter (Германия), MV-15-09 (Венгрия), Симонида (Сербия), GK Hollo (Венгрия), Webster (Канада), Wisdom (Канада), № 42 CIMMYT (США) и KS 96 WGRC 37 (США). Данные сорта показали хорошие результаты в условиях южной зоны Ростовской области. Остальные сорта коллекционного питомника рекомендуем включать в селекционную работу в соответствии с принципом комплементарности, как взаимно дополняющие сорта по выраженности того или иного признака или свойства.

Ключевые слова: озимая пшеница, массовая доля белка, клейковина, натура зерна, стекловидность, масса 1000 зерен

STUDY OF THE PARENT MATERIAL OF SOFT WINTER WHEAT FOR BREEDING FOR GRAIN QUALITY

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The sources of valuable traits for targeted use in the breeding of new winter wheat varieties with improved quality traits are presented. The results of the evaluation of the parent material on the expression of economically valuable features in the collection samples of soft winter wheat are presented. The paper presents data on 31 varieties of different ecological and geographical origin. Field experiments were conducted in 2018-2020 in the breeding rotation under the conditions of the southern zone of the Rostov region. Quality indicators of the varieties: thousand grain weight, protein content, quantity and quality of gluten in the grain, grain unit, total vitreousness, baking properties were determined by standard methods and GOSTs. As a result of the clustering of varieties, it is shown that the breeding program to create adaptive varieties with high grain quality should include as basic parent material the varieties which are included in the 5th and 6th clusters - L-19578 (Russia), Etana (Germany), Warwick (Canada), Akter (Germany), MV-15-09 (Hungary), Simonida (Serbia), GK Hollo (Hungary), Webster (Canada), Wisdom (Canada), No. 42 CIMMYT (USA), and KS 96 WGRC 37 (USA). These varieties showed good results in the southern zone of the Rostov region. The other varieties of the collection nursery are recommended to be included in the breeding work in accordance with the principle of complementarity, as mutually complementary varieties in the expression of a particular trait or property.

Keywords: winter wheat, mass fraction of protein, gluten, grain unit, vitreousness, thousand grain weight

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The authors declare no conflict of interest.

INTRODUCTION

Winter soft wheat is a crop with a high biological potential for productivity and grain quality in the southern zone of the Rostov region [1, 2]. Creating new varieties of winter soft wheat largely depends on the proper selection of starting material as an initial and crucial stage of the breeding process [3–6]. For successful wheat breeding, it's essential to identify and comprehensively study genetic sources and donors of valuable traits directly in the breeding regions [7, 8].

The purpose of the study is to identify the sources of valuable traits for targeted use in breeding new varieties with improved quality characteristics.

The research objectives are:

– selection of the most productive samples from the collection nursery for comprehensive study of grain and flour quality;

– carrying out variance and cluster analyses of experimental data;

– selection of the best varieties that significantly exceed the standard by the studied traits and properties for use in crossbreeding to create new genotypes with high grain quality.

MATERIAL AND METHODS

The study of collection varieties took place in field conditions from 2018 to 2020 at the laboratory of selection and seed production of intensive-type winter wheat and in the biochemical, technological, and agrochemical assessment laboratory of the Agrarian Scientific Center "Donskoy" (ASC "Donskoy").

The research object for determining the technological properties of grain and flour was 31 varieties of winter wheat of various ecological-geographical origins. The Ermak variety was used as a standard. The plot area was 3 m^2, with a two-time repetition, and the forecrop was autumn fallow. The test field soil was a powerful carbonated heavy loamy chernozem.

In the 2017/18 agricultural year, drought was noted during the active vegetation period of wheat (April - June). Precipitation during this period was 25.9 mm compared to the long-term norm of 165.3 mm. Daily average air temperatures exceeded long-term values in April by 0.8 °C, in May by 2.7 °C, and in June by 3.4 °C.

In the 2018/19 agricultural year, quality formation occurred under conditions of insufficient moisture, especially in June (10.8 mm, standard - 71.3 mm), and elevated temperatures (in May by 2.5 °C, in June by 4.7 °C). Moreover, a shortage of precipitation was noted in June compared to the long-term average by 100.3; 61.5, and 32.5 mm, respectively.

The grain quality formation period in the 2019/20 agricultural year was characterized by a large amount of precipitation in May (155.7% of the standard) and an optimal temperature (15.4 °C). It was favorable for the growth and development of soft winter wheat, despite the precipitation shortage (54.4% of the standard) and an elevated temperature regime (by 2.6 °C) in June.

The main quality characteristics of grain and flour were determined in the biochemical assessment laboratory of breeding material and grain quality of ASC "Donskoy". Grain nature was studied in accordance with GOST 10840–2017[1], overall grain vitreousness – according to GOST R 70629–2023[2]. The protein mass fraction in grain was determined using the infrared ana-

[1]GOST 10840-2017 Grain. Method for determining the natural weight. Moscow: Standardinform, 2019, 19 p.
[2]GOST R 70629-2023 Wheat. Determination of vitreousness by the optical-computer method. Moscow: Standardinform, 2023, 5 p.

lyzer SpektraStar 2200, the quantity and quality of gluten in the grain – according to GOST R 54478-2011[3], the falling number – in accordance with GOST 27676-88[4]. A trial laboratory baking was carried out using the remix method with re-kneading. Bread quality was assessed according to the methodological guidelines of the state commission for crop variety testing[5]. Data mathematical processing and cluster analysis were carried out using Microsoft Office Excel and Statistica 10 software. Euclidean distance was used as a similarity measure.

RESULTS AND DISCUSSION

The weight of 1000 grains is an essential element of productivity and a significant selection trait for yield selection. It also significantly affects the grain's appearance and milling properties. Breeders pay attention to this trait as it allows them to select not only sources of large grains but also varieties well-adapted to specific soil and climatic conditions; moreover, this trait is inherited well [9, 10]. It was found that, on average, over the years of study, the weight of 1000 grains ranged from 33.2 g (GK Hollo, Hungary) to 44.8 g (Eistanzuelo Benteveo, Uruguay), which according to the CMEA[6] classifier, characterizes varieties from small-grained to large-grained. Varieties like Eistanzuelo Benteveo (Uruguay) (44.8 g), Ling Xing 99 (China) (44.7), and Akter (Germany) (44.7 g) showed high values of this trait on average over 3 years of study, significantly exceeding the standard LSD_{05} = 1.5 g (see Table 1).

These samples are recommended to be used as sources of large grains.

In determining the quality of wheat grain, vitreousness is one of the most critical class-forming indicators, also characterizing its milling properties. The higher the grain's vitreousness, the higher its technological properties [11]. The overall vitreousness of the studied varieties ranged from 50% (Bombus, France) to 74%

Табл. 1. Показатели качества зерна сортов озимой мягкой в пшеницы в коллекционном питомнике, 2018–2020 гг.

Table 1. Grain quality indicators of soft winter wheat varieties in the collection nursery, 2018-2020

Variety	Origin	Weight of 1000 grains, g	Vitreousness, %	Grain unit, g/l
Ermak, standard	Russia	42,8	57	804
L-19578	»	42,0	57	799
Vinnichanka	Ukraine	38,5	58	815
Shestopalivka	»	41,0	53	805
Slavna	»	40,3	73	814
Chornyava	»	41,1	73	810
Simonida	Serbia	38,0	66	824
Zlatka	»	37,2	72	835
NS 405/00	»	35,8	54	786
№ 42 CIMMYT	USA	37,6	74	809
KS 96 WGRC 37	»	34,8	68	816
Warwick	Canada	37,3	51	817
Webster	»	36,1	55	811
Wisdom	»	33,7	52	807
Zhong Ping 1597	China	41,8	57	812
Fuimai 5	»	41,5	55	797
Ling Xing 99	»	44,7	74	809
Akter	Germany	44,7	57	814
Etana	»	36,6	58	786
Cubus	»	35,0	63	785
MV-15-04	Hungary	39,8	63	823
GK Cipo	»	39,7	63	818
GK Hollo	»	33,2	55	830
№ 71 CIMMYT	Romania	40,6	56	809
Fidelius	Austria	38,6	57	801
Tatsitus	»	37,4	62	804
CO 911	France	36,7	59	794
Seilor	»	38,3	74	811
Bombus	»	35,6	50	759
Dagmar	»	39,9	57	822
Eistanzuelo Benteveo	Uruguay	44,8	55	809
LSD_{05}	–	1,5	7	13

[3]GOST R 54478-2011 Grain. Methods for determining the quantity and quality of gluten in wheat. Moscow: Standardinform, 2012, 23 p.

[4]GOST 27676-88 Grain and products of its processing. Method for determining the fall number. Moscow: Standardinform, 2009, 5 p.

[5]Methodology of the state variety testing of agricultural crops. Technological evaluation of grain, groat and leguminous crops. Under the general editorship of M.A. Fedin. Moscow, 1988, 121 p.

[6]International CMEA Classifier of the genus Triticum L. L., 1984, 86 p.

(Sailor, France), (No. 42 CIMMYT, USA), and (Ling Xing 99, China). The maximum expression of the trait (> 70%) was noted for the following varieties: Slavna, Chornyava (Ukraine) (73%), Zlatka (Serbia) (72%), No. 42 CIMMYT (USA) (74%), Ling Xing 99 (China) (74%), Sailor (France) (74%). The selected varieties for grain vitreousness exceeded the Ermak variety (LSD_{05} = 7%) and can be used in breeding to improve this trait.

Grain nature is also an indicator of grain size and plumpness. The values of the nature of the studied varieties were established from 759 g/l (Bombus, France) to 835 g/l (Zlatka, Serbia). On average, over the years of the study, all studied varieties were characterized by high nature values and corresponded to the 1st quality class according to the GOST for wheat. The maximum values, which significantly exceeded the standard (LSD_{05} = 13 g/l) for this trait, were noted in the varieties, g/l: Warwick (Canada) (817), GK Cipo (Hungary) (818), Dagmar (France) (822), MV-15-04 (Hungary) (823), Simonida (Serbia) (824), GK Hollo (Hungary) (830), and Zlatka (Serbia) (835). These varieties are recommended for use as sources to improve the "natural weight" trait.

The problem of protein content in wheat grain as a breeding trait is complicated by the negative correlation with grain yield, making it challenging to select for both traits simultaneously. The protein content in the grain significantly influences baking properties, the biological value of the grain, and processed products [12, 13]. The average protein mass fraction in grain over the research years varied from 12.66% (Bombus, France) to 15.05% (L-19578, Russia) (see Table 2).

According to GOST 9353-2016[7], strong wheats are varieties with protein content not less than 14%. Based on this criterion, the following samples stood out significantly (LSD_{05} = 0.52%), %: L-19578 (Russia) (15.15), Zhong Ping 1597 (China) (14.48), Akter (Germany) (14.28), Etana (Germany) (14.16), Sailor (France) (14.24), No. 42 CIMMYT (USA) (14.15), KS 96 WGRC 37 (USA) (14.01), and Zlatka (Serbia) (14.08).

Табл. 2. Качество клейковинно-белкового комплекса и хлебопекарные свойства муки из сортов озимой мягкой пшеницы в коллекционном питомнике, 2018–2020 гг.

Table 2. The quality of the gluten-protein complex and the baking properties of flour from soft winter wheat varieties in the collection nursery, 2018-2020

Variety	Protein mass fraction, %	Gluten content, %	Gluten quality, GDI device units	VB, ml	TBS, score
Ermak, standard	13,88	24,7	71	600	3,8
L-19578	15,05	31,6	76	670	4,1
Vinnichanka	13,76	26,6	84	593	3,6
Shestopalivka	13,71	26,5	81	610	3,7
Slavna	13,75	24,2	81	613	3,7
Chornyava	13,43	24,4	81	583	3,5
Simonida	13,57	29,1	86	687	4,4
Zlatka	14,08	26,7	84	607	3,8
NS 405/00	13,46	22,5	69	563	3,3
№ 42 CIMMYT	14,15	30,8	90	693	4,2
KS 96 WGRC 37	14,01	30,0	85	693	4,3
Warwick	13,28	25,6	88	657	4,1
Webster	13,09	22,9	87	690	4,2
Wisdom	13,24	23,9	84	673	4,1
Zhong Ping 1597	14,48	30,9	105	600	3,4
Fuimai 5	12,69	22,8	79	593	3,5
Ling Xing 99	13,93	28,6	99	620	3,7
Akter	14,28	27,6	87	643	4,1
Etana	14,16	25,1	89	670	4,1
Cubus	13,61	24,4	84	563	3,1
MV-15-04	13,64	25,5	84	647	3,8
GK Cipo	13,54	27,8	81	630	3,8
GK Hollo	13,60	30,4	87	683	4,1
№ 71 CIMMIT	13,91	25,7	81	610	3,6
Fidelius	13,29	23,4	68	590	3,6
Tatsitus	13,76	25,2	73	530	3,0
CO 911	13,54	24,1	84	617	3,8
Seilor	14,24	27,9	82	587	3,4
Bombus	12,66	25,1	79	637	3,9
Eistanzuelo Benteveo	13,22	25,3	87	610	3,4
Dagmar	13,30	24,5	75	613	3,6
LSD_{05}	0,52	1,1	5	25	0,1

Note. VB - volumetric yield of bread, ml; TBS - total baking score, score.

[7]GOST 9353-2016 Wheat. Technical conditions. Moscow: Standardinform, 2019,12 p.

These samples can be used as parental forms for crossbreeding.

Seven varieties were characterized by maximum gluten content in grain, meeting the requirements for the 2nd quality class (not less than 28.0%). The varieties with the highest values of this trait (> 30%) were, %: L-19578 (Russia) (31.6), No. 42 CIMMYT (USA) (30.8), Zhong Ping 1597 (China) (30.9), and GK Hollo (Hungary) (30.4). These varieties significantly exceeded the standard (LSD_{05} = 1.1%). These collection samples are recommended for use as sources to improve the "amount of gluten in grain" trait.

The Gluten Deformation Index (GDI) describes physical and rheological properties of gluten (elasticity, stretchability). Among the studied varieties in the collection nursery, GDI values varied widely – from 68 units (Fidelius, Austria) to 105 units (Zhong Ping 1597, China). This corresponded to the 1st-3rd quality groups. For producing quality bread products, the optimal gluten quality in grain for baking is 70-90 GDI units, i.e., the satisfactory upper range of the 1st group and the lower range of the 2nd group [14, 15].

Conducting trial laboratory baking is the final stage in determining the baking properties of winter soft wheat varieties. Based on the conducted studies, varieties have been identified that have fully realized baking properties and were characterized by the maximum volumetric yield of bread and overall bread rating, ml, score: L-19578 (Russia) (670, 4.1), Simonida (Serbia) (687, 4.4), No. 42 CIMMYT (USA) (693, 4.2), KS 96 WGRC 37 (USA) (693, 4.3), Webster (Canada) (690, 4.2), Wisdom (Canada) (673, 4.1), Etana (Germany) (670, 4.1), and GK Hollo (Hungary) (683, 4.1). These standout samples are recommended for use as parental forms for creating baking-type varieties.

To identify the genotypes possessing a combination of economically valuable traits affecting baking properties, with their subsequent inclusion in hybridization, cluster analysis of winter soft wheat collection samples was conducted. It was based on yield, grain weight, vitreousness, weight of 1000 grains, protein content, quantity and quality of gluten, bread volume yield, and overall bread baking assessment.

As a result of the analysis, a dendrogram was constructed with the distribution of samples into 7 clusters (see the figure, Table 3).

The first cluster included 6 varieties characterized by large grain (44.0 g), high grain density (808 g/l), GDI of 78 device units (1st group). However, their baking properties were marked at the level of valuable wheat (see table 3).

The second cluster represented 7 samples characterized by large grains (weight of 1000 grains 44.5 g), high grain density (810 g/l), and high gluten content (25.4%). The Gluten Deformation Index for this group of the varieties was 82 device units (2nd group), which influenced the increased bread volume yield (615 ml) (see Table 4).

The third cluster consisted of 3 varieties, which formed maximum values for weight of 1000 grains (45.7 g), grain density (818 g/l), protein content (14.16%), and gluten content in grain (28.7%). These samples can be used for hybridization as sources to improve the gluten-protein complex.

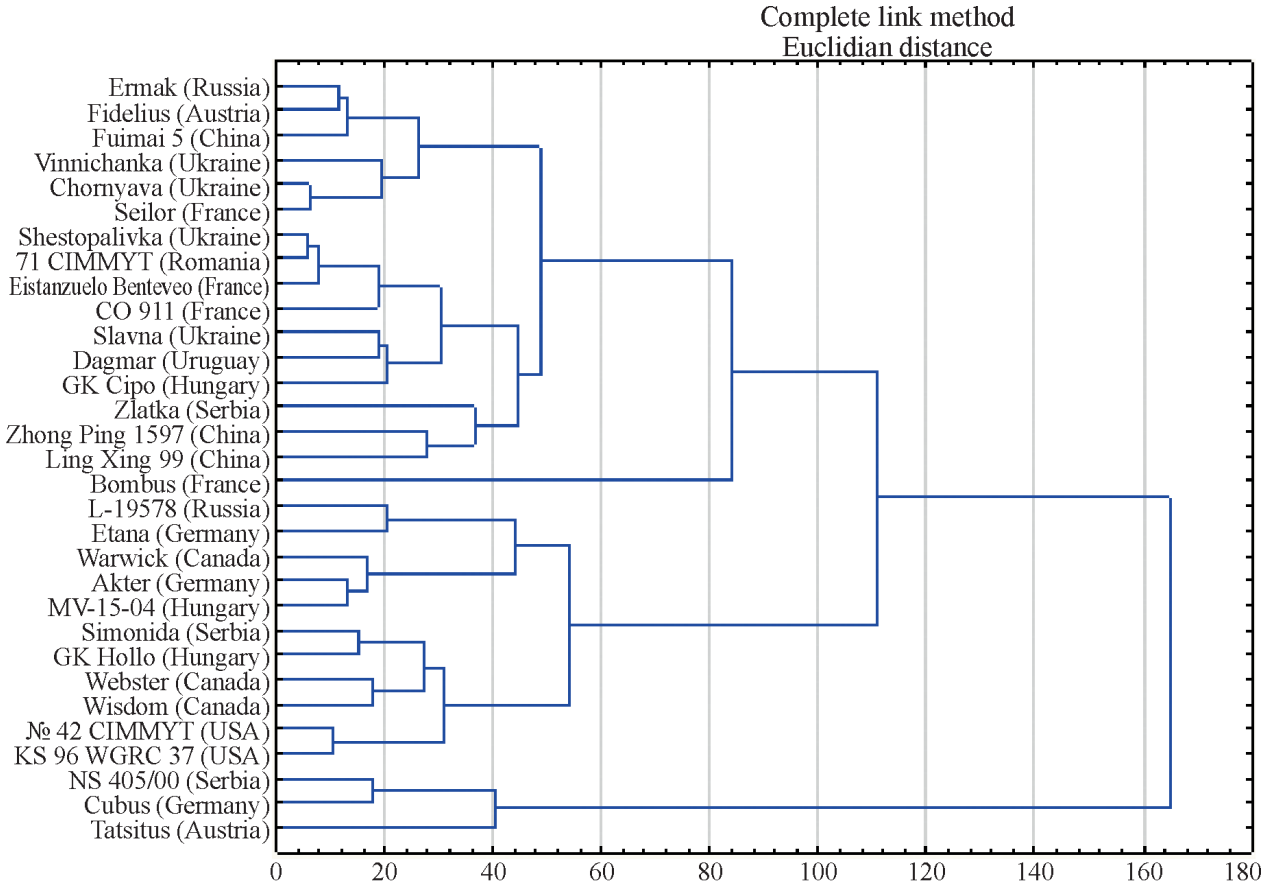
The fourth cluster was represented by one variety, Bombus (France), which had high yield (12.2 t/ha) but low protein content (12.66%) and the following physical quality traits: grain density of 759 g/l, vitreousness of 57%, and the weight of 1000 grains of 38.2 g.

The fifth cluster included 5 varieties with the weight of 1000 grains (44.3 g), high grain density (808 g/l), maximum protein content (14.08%), high gluten content in grain (27.1%), and good baking properties (bread volume yield of 657 ml and overall bread rating of 4.0 points).

The sixth cluster included 6 varieties, where all the studied traits and properties were best expressed, affecting bread quality.

The seventh cluster consisted of 3 varieties with a low gluten content (24.0%). The Gluten Deformation Index was 75 device units, resulting in a low bread volume (552 ml) and an overall score of 3.2 points.

The varieties of the collection nursery, included in the 5th and 6th clusters, are of greatest interest for the development of baking varieties.



Распределение сортов озимой мягкой пшеницы на кластеры по урожайности и комплексу признаков, характеризующих качество, 2018–2020 гг.

Distribution of soft winter wheat varieties into clusters according to productivity and a set of traits which characterize quality, 2018-2020

Табл. 3. Распределение сортов коллекции по кластерам

Table 3. Distribution of soft winter wheat varieties according to clusters

Cluster	Variety
1st	Ermak (Russia), Fidelius (Austria), Fuimai 5 (China), Vinnichanka (Ukraine), Chornyava (Ukraine), Seilor (France)
2nd	Shestopalivka (Ukraine), 71 CIMMYT (Romania), Eistanzuelo Benteveo (France), CO 911 (France), Slavna (Ukraine), Dagmar (Uruguay), GK Cipo (Hungary)
3rd	Zlatka (Serbia), Zhong Ping 1597 (China), Ling Xing 99 (China)
4th	Bombus (France)
5th	L-19578 (Russia), Etana (Germany), Warwick (Canada), Akter (Germany), MV-15-04 (Hungary)
6th	Simonida (Serbia), GK Hollo (Hungary), Webster (Canada), Wisdom (Canada), № 42 CIMMYT (USA), KS 96 WGRC 37 (USA), KS 96 WGRC 37 (USA)
7th	NS 405/00 (Serbia), Cubus (Germany), Tatsitus (Austria)

CONCLUSION

When creating varieties of winter soft wheat adapted to the climatic conditions of the southern zone of the Rostov region, an important step is the most comprehensive study of the sources of useful traits and properties for use as starting material. As a result of the cluster analysis, it is believed that the breeding program for creating adaptive varieties with high grain quality should include the varieties from the 5th and 6th clusters as the basic starting material. These are L-19578 (Russia), Etana (Germany), Warwick (Canada), Akter (Germany), MV-15-09 (Hungary), Simonida (Serbia), GK Hollo (Hungary),

Табл. 4. Характеристика кластеров по урожайности и качеству зерна
Table 4. Characteristics of clusters according to productivity and grain quality

Trait	Cluster						
	1st	2nd	3rd	4th	5th	6th	7th
Grain unit weight, g/l	806	810	818	759	808	816	792
Vitreousness, %	62	59	68	50	57	62	60
Weight of 1000 grains, g	44,0	44,5	45,7	38,2	44,3	37,5	38,8
Protein mass fraction, %	13,55	13,57	14,16	12,66	14,08	13,61	13,61
Gluten content, %	25,0	25,4	28,7	25,1	27,1	27,8	24,0
Gluten deformation index, units of the device	78	82	96	79	85	86	75
Volumetric yield of bread, ml	591	615	609	637	657	687	552
Total baking score, score	3,6	3,6	3,6	3,9	4,0	4,2	3,2
Yield, t/ha	11,2	11,5	10,1	12,2	11,5	11,1	11,5

Webster (Canada), Wisdom (Canada), No. 42 CIMMYT (USA), and KS 96 WGRC 37 (USA). These varieties have shown the highest results in the conditions of the southern zone of the Rostov region. Other varieties from the collection nursery are recommended to be included in the breeding work according to the principle of complementarity, complementing the basic varieties by expressing a particular trait or property.

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