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Variability of Winter Wheat Quality Features in Northern Trans-Urals

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Abstract

The studies were carried out in laboratory conditions on the basis of Agrotechnological Institute of Northern Trans-Ural State Agricultural University. The studies include 5 varieties of winter wheat grown in 2009-2011 in three agroclimatic zones of Tyumen Region: sub-regional (Nizhnetavdinsky state crop testing site), northern forest steppe (Yalutorovsky state crop testing site), southern forest steppe (Berduzhsky state crop testing site). Bashkirskaya variety -- 10 (45 g) demonstrated the highest potential in the formation of a 1000 grain weight. The same variety has the highest range of variability (11.7 g) and the variability coefficient (10.9%) indicates average variability. Other varieties showed minor variability of characteristic (V = 8.7-9.9%). Winter wheat varieties varied in terms of average hardness, at the same time the level of values of all varieties (66-77%) corresponded to the standards of high classes according to GOST. Novosibirskayaaya 32 (61-93%) and Bashkirskaya 10 (60-86%) varieties were the most stable in forming the required value of characteristic. The average gluten content in a grain of winter wheat varieties were corresponded to the standards of the third class according to GOST. Novosibirskaya 32 variety (V = 8.5%) had minor variability of the characteristic, while other varieties demonstrated the average variability. A significant proportion of the effect of the ``variety'' factor on variability of such features as a 1000 grain weight (56.5%), grain-unit (50.5%) and hardness (45.1%) was established. The amount of gluten depended more on growing environment (35.5%) and interaction of factors (39.3%). The quality of gluten was much influenced by growing environment (52.2%).

Keywords: 1000 grain weight; grain-unit; hardness; gluten; coefficient of variability

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1. Introduction

Wheat holds a significant share in the total raw materials for food production. Therefore, quality improvement of this grain, increase the yield of strong and valuable wheat should be one of the key tasks of agricultural science and production. However, in recent years there has been a significant decrease in wheat grain quality [1-6]. While in 2012 the share of food wheat of the third class in the total volume of grain collection reached about 50%, in 2013-2015 it averaged 36% and in 2016-2018 it decreased to 19%. Thus,

there is the problem of providing flour milling and bakery industry with high-quality raw materials and the population with high-quality grain products.

Among factors that influenced the current situation there are economic factors, i.e. lack of motivation of producers for the production of high-quality grain, and technological factors -- the technologies are not always aimed at producing grain of certain qualitative parameters. In specific soil-climatic conditions it is also necessary to identify the stability of cultivated varieties in the formation of grain that meets the requirements of high classes for food.

In Western Siberia, winter wheat occupies small areas in grain crops. However, the interest of producers to this culture is quite high since the production of mature high quality grain in the second half of July is critical for this region.

The studies of some authors in Northern Trans-Urals are devoted to the technology of cultivation and production of high-quality grain [7-13]. However, the problem of high quality grain production meeting basic requirements remains quite relevant.

The purpose of the study is to analyze the degree of variability of winter wheat grain quality characteristics during their cultivation in different agroclimatic zones of Tyumen Region.

2. Materials and Methods

The studies were carried out in laboratory conditions on the basis of Agrotechnological Institute of Northern Trans-Ural State Agricultural University. The studies include 5 varieties of winter wheat grown in 2009-2011 in three agroclimatic zones of Tyumen Region: sub-regional (Nizhnetavdinsky state crop testing site), northern forest steppe (Yalutorovsky state crop testing site), southern forest steppe (Berduzhsky state crop testing site). Composition of wheat varieties: Novosibirskayaaya 32 - standard, Novosibirskayaaya 40, Novosibirskayaaya 51, Biiskaya winter wheat, Bashkirskaya 10. The number of samples of each variety -- 9.

The study of winter wheat varieties in field experiments was carried out by the State Test Service in accordance with approved variety test method. The predecessor -- complete fallow.

Grain quality assessment was carried out in accordance with GOST methods. Mathematical processing of research results was performed via dispersion and variability analyses according to B.A. Dospekhov (1985).

3. Results

The studies were carried out on the basis of a 1000 grain weight, which is the key indicator of physical properties of wheat indicating some level of nutrients in it. The characteristic is considered relatively stable and genetically conditioned. However, it is subject to growth conditions and can vary considerably. During the period of grain formation and grain-filling period, lack of moisture in the soil, high temperature and low relative humidity can negatively affect a 1000 grain weight. I.E. Likhenko and V.P. Shamanin [14] showed a significant variability in a 1000 grain weight of wheat of Chernyava 13 variety depending on the conditions of the year: from 29.2 to 47.2 g.

Large, well-filled grain is highly valued in processing: from wheat, a 1000 grain weight of which is higher than 40 g, it is possible to produce a larger yield of flour by 3-5% compared to a fine fraction, a 1000 grain weight of which is less than 25 g [15].

In our studies Bashkirskaya 10, Novosibirskaya 40, Novosibirskaya 51 varieties of winter wheat had the largest 1000 grain weight: excess over the standard made 5.3; 3.8; 3.1 g, respectively (Table 1).

Table 1: Variability of a 1000 winter wheat grain weight.

Variety	Average, g	Limits of variability, g	Range of variability, g	V, %
Novosibirskayaaya 32, st	33.0	28.8 -- 36.9	8.1	9.9
Biiskaya winter wheat	32.8	29.8 -- 37.4	7.6	9.1
Novosibirskayaaya 40	36.8	31.6 -- 40.3	8.7	8.7
Novosibirskayaaya 51	36.1	31.9 -- 40.2	8.3	8.8
Bashkirskaya 10	38.3	33.9 -- 45.6	11.7	10.9

Bashkirskaya 10 (45 g) showed the highest potential in the formation of this indicator. The same variety has the highest range of variability (11.7 g) and the coefficient of variability (10.9%), which indicates an average degree of variability. Other varieties varied slightly in terms of the range of variability (7.6-8.7 g) and showed minor variability of the characteristic (V = 8.7-9.9%).

The grain-unit is considered an indirect criterion of its flour-milling properties. High grain-unit characterizes good grain plumpness and ensures high flour yield. Underdeveloped wheat with low grain-unit has reduced yield of this valuable product: at a grain-unit below 740 g/l the flour-milling properties of wheat grain are strongly deteriorated: flour yield is decreased [15].

According to Y.V. Kolmakov [16], the grain-unit can determine the degree of variety resistance to unfavorable growing conditions -- drought, fall of temperature or increased moisturization during grain-filling period and maturation, which is often typical for Western Siberia.

The interstate standard GOST 9353-2016 sets requirements on the grain-unit value to food grain of wheat: for the first and second classes -- not less than 750 g/l, the third -- not less than 730 g/l, the fourth class -- not less than 710 g/l, for the fifth class the value of this indicator is not limited.

According to the average grain-unit among the varieties of winter wheat Novosibirskaya 40, Novosibirskaya 51, Biiskaya winter wheat exceeded the standard by 30; 29 and 27 g/l, respectively (Table 2).

Table 2: Variability of winter wheat grain-unit.

Variety	Average, g	Limits of variability, g	Range of variability, g	V, %
Novosibirskayaaya 32, st	747	629 - 820	191	10.4
Biiskaya winter wheat	774	680 - 811	131	5.7
Novosibirskayaaya 40	777	720 - 811	91	3.9
Novosibirskayaaya 51	776	736 - 810	74	3.5
Bashkirskaya 10	753	693 - 777	84	4.4

The maximum grain-unit values (810-820 g/l) indicate the possibilities of these varieties, as well as the standard variety to form high grain-unit under favorable conditions. Novosibirskaya 51 has the smallest range of variability of the characteristic (74 g/l), which characterizes the variety as relatively resistant to the formation of a grain-unit in different growing conditions. This confirms the lowest coefficient of variability of the characteristic (3.5%). Novosibirskaya 32 standard (191 g/l) has the largest range of variability of a grain-unit index and the average degree of variability (V = 10.4%). The coefficient of variability for other varieties made 3.5-5.7% indicating a slight degree of variability.

Another important indicator of wheat quality is its hardness (endosperm consistency). The endosperm consistency depends on the form of binding of protein substances with starch grains. In vitreous endosperm a large amount of protein is closely related to starch grains, broad layers of the so-called attached protein are formed. This protein is not removed from starch granules through heavy machining. The other part of protein is located between starch grains thus forming wedgeprotein that is released when ground. Farinaceous grains contain more wedgeprotein. Higher yield of the best varieties of flour

(coarse-granular, white wheat flour) is obtained at flour milling plants when grinding vitreous grain [15]. Many researchers consider grain hardness as a grading factor and note that this indicator may vary significantly depending on soil-climatic conditions.

The following requirements of the standard on hardness are established for food wheat grain: first and second class -- at least 60%, third -- at least 40%, for the fourth and fifth classes the value of the characteristic is not limited.

In our study, the varieties of winter wheat were different in terms of the average values of hardness, at the same time the level of values (66-77%) of all varieties corresponded to standards of high classes according to GOST (Table 3). Considering the limits of variability, it shall be noted that Novosibirskaya 32 standard (61-93%) and Bashkirskaya 10 (60-86%) have the most stable formation of the required value of characteristic.

Novosibirskaya 32 standard has the highest range of variability of the indicator (32%) and coefficient of variability (13.9%). For other varieties the coefficient of variability was in the range of 10.6-13.3%, which also characterizes the average degree of variability of the characteristic.

Table 3: Variability of winter wheat grain hardness.

Variety	Average, g	Limits of variability, g	Range of variability, g	V, %
Novosibirskayaaya 32, st	77	61 - 93	32	13.9
Biiskaya winter wheat	70	57 - 84	27	12.6
Novosibirskayaaya 40	66	53 - 78	25	10.6
Novosibirskayaaya 51	68	56 - 79	23	12.7
Bashkirskaya 10	74	60 - 86	26	13.3

Wheat grain gluten serves the basis for the production of bread of some quality. Protein substances that constitute gluten (gliadin and glutenin) provide wheat dough with elastic properties, which affects the yield and quality of bread products. Baking flour strength is associated with gluten. The content and quality of gluten depends on gas-retaining ability of dough, and on this indicator -- volume, appearance and general assessment of bread. The accumulation of protein and gluten in wheat grains to a large extent depends on the amount of available nitrogen in soil, total nutrients in soil, its humidity, meteorological factors. In the conditions of Northern Trans-Urals, the use of fertilizers contributed to a significant increase in the content of gluten in grains [17]. The increase of this indicator in quickly ripening varieties under the influence of fertilizers reached 9.3%, mid-ripening variety varieties -- 9.7%. On average, quickly ripening varieties exceeded mid-ripening varieties by 2-3%. The highest content of

gluten is noted in Novosibirskaya 15 and Zlatosara, which were characterized by the frequency of grain formation with gluten --28% and higher.

The current GOST requirements to wheat grain provide for gluten level for the first class -- at least 32%, second class -- at least 28%; third class -- at least 23%; fourth -- at least 18%; for the fifth class the value of this indicator is not limited.

The assessment of winter wheat varieties by the amount of gluten in the grain are shown in Table 4. Analyzing the average values, it shall be noted that the content of gluten in all varieties met the standards of the third class, i.e. the level that ensures the production of bread of standard quality. However, the range of variability of the characteristic indicates that in some samples the amount of gluten decreased to fourth class standards. At the same time, it is necessary to note the potential of varieties to form grain with high content of gluten -- at the level of requirements of the second class and even the first -- Novosibirskaya 51 (32.2%).

The highest range of is typical for Novosibirskaya 40 (11%), for the same variety the coefficient of variability was also the highest (12.7%). Low range of variability was typical for Novosibirskaya 32 standard (7.2%). The coefficient of variability of the characteristic of this variety characterizes a minor degree of variability. For other varieties the variability of the gluten content in grain was rated as average.

Table 4: Variability of gluten content in winter wheat grain.

Variety	Average, g	Limits of variability, g	Range of variability, g	V, %
Novosibirskayaaya 32, st	26.4	22.4 -- 29.6	7.2	8.5
Biiskaya winter wheat	24.1	19.3 -- 29.0	9.7	11.7
Novosibirskayaaya 40	25.5	19.6 -- 30.6	11.0	12.7
Novosibirskayaaya 51	26.1	22.6 -- 32.2	9.6	11.3
Bashkirskaya 10	24.6	21.4 -- 29.7	8.3	10.7

Gluten quality and its elasticity are assessed on FDM unit in conventional units. The requirements of the standard provide for the quality of gluten of the 1st and 2nd classes not lower than the I group (43-77 FDM units), 3rd and 4th classes -- not lower than the II group (18-102 FDM units).

Table 5 shows that in terms of the average values (67-71 FDM units) the quality of gluten of all varieties was in the first group. However, this characteristic has a wide range of variability -- from the first to the second group, and for Novosibirskaya 51 it even exceeds the limits of the second group (105 FDM units).

Novosibirskaya 32 and Novosibirskaya 51 have the highest range of gluten quality variability (55 FDM units), while Novosibirskaya 40 has the smallest (35 FDM units). The quality of gluten in Novosibirskaya 40 was characterized by an average degree of variability (V = 18.4%), for other classes the variability of the characteristic is significant (V = 20.1-24.2%)

Table 5: Variability of gluten quality in winter wheat grain.

Variety	Gluten quality, FDM unit			V, %
	Average, g	*Limits of variability, g*	*Range of variability, g*	
Novosibirskayaaya 32, st	70	45 - 100	55	24.2
Biiskaya winter wheat	67	45 - 90	45	20.1
Novosibirskayaaya 40	68	55 - 90	35	18.4
Novosibirskayaaya 51	71	50 - 105	55	22.2
Bashkirskaya 10	70	50 - 95	45	20.2

The falling number reflects the state of carbohydrate-amylase grain complex. The value of this characteristic is related to alpha-amylase enzyme activity. In normal grain, the activity of this enzyme is low, and it increases as the grain germinates. As a result, the state of starch changes -- it is hydrolyzed to form water-soluble substances -- dextrins and sugars. The state of the carbohydrate-amylase complex can be assessed even before the appearance of seedlings using an indirect method of assessing alpha-amylase activity according to the falling number (time in seconds spent on gelatinization and immersion of a plunger in a water-flour suspension tube).

The requirements of the state standard provide for the value of the falling number for the 1st and 2nd classes amounting to not less than 200 sec., for the 3rd -- not less than 150 sec., for the 4th class -- not less than 80 sec., for the 5th class the value of this indicator is not limited. In the conditions of the northern forest steppe of Tyumen Region, in the experiment to study the varieties of spring wheat of different groups of ripeness on increasing backgrounds of mineral fertilizers [17], it was found that quickly ripening variety have higher falling number compared to mid-ripening varieties. The value of the characteristic was decreasing in options with high fertilizer rates, as well as in late sowing period.

The average values of the index given in Table 6 make 343-421 sec. for winter wheat varieties, which meets the requirements of the first class according to GOST. At the same time, it shall be noted that the value of the characteristic of Novosibirskaya 32 varies significantly: range of variability -- 201-464, coefficient of variability -- 32%. The

average degree of variability of the characteristic is typical for Novosibirskaya 40 (V = 14.1%) and Bashkirskaya 10 (V = 14.3%). A minor variability of a falling number was typical for Biiskaya winter wheat (V = 8.9%) and Novosibirskaya 51 (V = 9.6%).

The variability of winter wheat grain quality characteristics is caused by the influence of the variety and growing conditions at a certain point (grade area) in certain years (Table 7).

Table 6: Variability of falling number of winter wheat grain.

Variety	Falling number, sec.			V, %
	Average, g	*Limits of variability, g*	*Range of variability, g*	
Novosibirskayaaya 32, st	360	201-464	263	32.0
Biiskaya winter wheat	421	376-469	93	8.9
Novosibirskayaaya 40	415	343-479	136	14.1
Novosibirskayaaya 51	414	374-453	79	9.6
Bashkirskaya 10	343	283-417	134	14.3

Table 7: Share of influence of ``variety'' and ``growing location'' on variability of quality indicators of winter wheat grain.

Indicator	Share of influence, %		
	A (variety)	B (location)	A-B interaction
1000 grain weight	56.5	31.7	11.1
Grain-unit	50.5	39.1	9.9
Grain hardness	45.1	28.6	21.1
Gluten content	24.9	35.5	39.3
Gluten quality	12.1	52.2	29.5
Falling number	27.3	33.7	36.6

The variability of such indicators as a 1000 grain weight and the grain-unit is more related to the influence of the ``variety'' factor (the share of influence of this factor is 56.5 and 50.5%). However, the growing location (31.7 and 39.1%) also had a significant impact. The share of a variety (45.1%), growing location (28.6%) and interaction of these factors (21.1%) is very significant in the variability of grain hardness. The gluten content is related to the influence of the growing location (35.5%) and the interaction of factors (39.3%), and the share of the influence of the variety (24.9%) is also significant. The quality of gluten was greatly influenced by growing conditions (52.2%), to a lesser extent by the interaction of factors (29.5%), the impact of the variety was negligible (12.1%). In the variability of the drop rate, the share of contribution of growing conditions (33.7%)

slightly dominated the share of the contribution of the variety (27.3%), the interaction of the two factors was 36.6%.

The study showed a rather high potential of grain quality of winter wheat varieties in the conditions of Northern Trans-Urals. As a positive aspect, there is minor variability of a 1000 grain weight and a grain-unit. Average variability is typical for hardness and gluten content. The quality of gluten in most varieties has significantly changed. In terms of the degree of variability of the falling number the wheat variety varied significantly: coefficient of variability ranged from 8.9 to 32%.

4. Conclusion

The 1000 grain weight and the grain-unit of winter wheat varieties showed minor variability. In terms of the 1000 grain weight, Bashkirskaya 10 had the highest indicators, in terms of the grain-unit -- Novosibirskaya 40, Novosibirskaya 51 and Biiskaya winter wheat.

The average values of gluten content in the grain of winter wheat varieties were in accordance with the GOST standards of the third class. Minor variability of the characteristic was typical for Novosibirskaya 32 standard (V = 8.5%), the average degree -- indicators of other varieties.

A significant proportion of the effect of the ``variety'' factor on variability of such features as a 1000 grain weight (56.5%), grain-unit (50.5%) and hardness (45.1%) was established. The amount of gluten depended more on growing environment (35.5%) and interaction of factors (39.3%). The quality of gluten was much influenced by growing environment (52.2%).

Conflict of Interest

The authors have no conflict of interest to declare.

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