Genetic resistance of oat of West Siberian breeding to contrasting weather conditions and mineral nutrition level

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Abstract. The publication presents the results of the study of three modern common oat varieties of West Siberian breeding for response to different levels of agricultural background in contrasting moistening weather conditions. The research was carried out in the northern forest-steppe of the Trans-Urals. The soil is leached thin chernozem, medium-humus, heavy-loamy. The following varieties were studied: Talisman, Otrada, and Foma. By applying fertilizers in the experiment, the following agricultural backgrounds were created: control, without fertilizers; medium N\textsubscript{60}P\textsubscript{20} kg/ha of active substance; increased - N\textsubscript{90}P\textsubscript{40}; high - N\textsubscript{150}P\textsubscript{60}; very high – N\textsubscript{200}P\textsubscript{80} kg/ha. It was found that the Otrada and Foma varieties have a higher resistance to acute arid conditions compared to the Talisman variety. In a year favorable for moisture due to mineral fertilizers, the maximum yield was obtained for: Talisman – 5.62; Otrada – 6.16 and Foma – 5.78 t/ha of grain. In acutely arid conditions, the Talisman reacted more negatively, the yield of which was equal to 2.30 t/ha. In other varieties, the yield reached 3.11 and 3.36 t/ha, respectively. During the research, it was found that the Otrada and Foma varieties belong to the group of high-intensity varieties recommended for Western Siberia. Biochemical analysis of grain and calculation of influence strength indicator showed that the protein content under the action of fertilizers increases from 6.1-7.0 \textsuperscript{\%} to 8.4-118\%, the Talisman variety had minimal response to fertilizers, where the protein content reached 10.6\% only in a dry, hot year. It was revealed that the fat content in oat grain depends only on the variety – the influence strength indicator is 88.9\%. The starch content is determined by the weather conditions of the year (36.1\%), but varietal features are distinguished.

1. Introduction
Western Siberia is a region of risky farming. It combines unfavorable climatic conditions and low-fertile soils [1]. If humanity has learned to regulate the fertility of arable land effectively enough, then it is still impossible to resist adverse weather conditions. It is for this reason that Western Siberia was not considered as an agricultural region for a long time. During the development of Siberia, peasants have repeatedly attempted to grow traditional crops, including cereals, potatoes, and flax [2]. As local historians note, the harvest of wheat, winter rye, and oats obtained in Siberia, on average, was not inferior to the European part of Russia [3].

Nevertheless, in some years, it was not possible to collect grain from the fields – it did not ripen or the crops dried up in July. For this reason, grain in Siberia was grown only for its own needs and for
developing animal husbandry. Local varieties were required, in which resistance to temperature changes, drought, and low fertility of local soils was genetically embedded. Siberian varieties of grain crops should have certain features: precocity; reduced development of the second half of the growing season; do not lodge and do not germinate on the root [4, 5]. The combination of such features makes them unique relative to European varieties of domestic breeding [6, 7].

Oat tolerates high temperatures much worse than spring wheat and barley. After 4-5 hours of exposure to temperatures of more than 30 degrees, the operation of the leaf apparatus is disrupted, which leads to a decrease in plant productivity. Good soil moisture can reduce the temperature stress of oat, but this is extremely rare in Western Siberia. Extremely high temperatures (>40°C) lead to disruption of generative development and pollen sterilization. This is precisely the limitation of the oat culture spread south of the middle latitudes. High air temperature and low soil humidity in the second half of the growing season inevitably lead to the formation of fine grain and change in its biochemical composition.

With the advent of a wide range of mineral fertilizers, in the 70s of the XX century, research began on the development of the Siberian fertilizer system. Many grain crops, in particular oat, reacted very strongly to the high agricultural backgrounds created by mineral fertilizers [5]. Oat crops on fertilized fields began to lodge, delayed maturation, which is critical in Siberia, grain quality was deteriorated. Information about outbreaks of grain crop diseases provoked by high doses of fertilizers began to appear in the scientific literature. The solution to the problems caused by fertilizers, it would seem, was in the development of a zonal fertilizer system. At the beginning of the XXI century, agronomists announced a technological solution to the problems of interaction between crops and fertilizers. Nevertheless, almost immediately they had to admit that the fertilizer system works effectively on the medium agricultural background, where it is planned to obtain a yield of grain crops of no more than 4.0 t/ha. At high agricultural backgrounds, providing yields of more than 5.0 t/ha, its efficiency decreases, and as the experience of many years of research has shown, the genetic characteristics of varieties are a limiting factor [8, 9]. This is most clearly manifested in the grain biochemical composition. Currently, breeders necessarily consider the agricultural background and at the genetic level fix the properties necessary for Siberian varieties. In recent years, the Research Institute of Agriculture of the Northern Trans-Urals has developed new oat varieties that are most adapted to the contrasting weather conditions of Western Siberia. These include varieties: Otrada, Talisman, Foma, which are sown not only in the Tyumen region, but also in the Far East, Kazakhstan, and the European part of Russia.

The purpose of the research was to study the yield formation and analysis of the biochemical composition of oat grain of Siberian breeding on different agricultural background under contrasting weather conditions.

2. Materials and Methods
The research was carried out at the experimental field of the Department of Soil Science and Agrochemistry of the State Agrarian University of the Northern Urals, which is located near the village of Uteshevo of the Tyumen district. The field is located in the northern forest-steppe of the Trans-Urals. The soil of the site is leached chernozem, minor, heavy loamy, formed on the cover carbonate loams. A detailed description of morphogenetic features, physico-chemical and agrochemical properties can be found in a previously published article [10]. The following oat varieties were taken as an object of research: Talisman, Otrada, Foma of West Siberian breeding, which were grown at various agricultural background:
- natural (without fertilizers). The yield was formed due to the natural reserves of nutrients in the soil;
- medium. N_{60}P_{20} kg/ha of the active substance was introduced. The dose of fertilizers provided nutrition for the formation of an oat crop of 3.0 t/ha;
- increased. N_{90}P_{40} kg/ha was introduced. For the planned yield of 4.0 t/ha of grain;
- high. Application dose N_{150}P_{60} kg/ha, providing a yield of 5.0 t/ha
very high. The maximum agricultural background formed by applying N\textsubscript{200}P\textsubscript{80} kg/ha, for the planned yield of 6.0 t/ha.

In the experiment, ammonium nitrate with a nitrogen content of 34.5% and ammophos, in which 12% nitrogen and 52% phosphorus, were used. Potassium fertilizers were not used, since the chernozem soils of the Trans-Urals have high reserves of potassium available for plants. Natural soil reserves are sufficient to obtain a grain yield of over 6.0 t/ha. Fertilizers were applied in the spring for pre-sowing cultivation. The soil treatment system is a dump multi-depth one.

Talisman oat variety. It was bred by the Agricultural Research Institute of the Northern Trans-Urals together with the Narym SBS by the method of individual selection from a hybrid combination of Flamingnova × Metis. A variety of mutica. This is a medium-ripened variety, resistant to lodging and grain shedding. Medium resistant to drought. It has been cultivated in the Tyumen region since 2002.

Otrada oat variety. It was bred by the Agricultural Research Institute of the Northern Trans-Urals Research Institute by hybridization of varieties (WW 170079 × Rs 39) × (Mutika 600 × Risto) with subsequent individual selection. A variety of mutica. A medium-ripened variety, resistant to lodging, grain shedding and medium-resistant to spring-summer drought. It has been included in the State Register for the Tyumen Region since 2013.

Foma oat variety. It was bred by the Agricultural Research Institute of the Northern Trans-Urals Research Institute by the method of step-by-step hybridization followed by selection from a hybrid population (WW 170079 × Rs 39) × (Mutica 600 × Risto). Sibs. A variety of mutica. Plants form a strong culm, resistant to lodging. Variety is resistant to grain shedding and medium-resistant to spring-summer drought. It has been included in the State Register for the Tyumen Region since 2014.

During harvesting, when determining the oat yield on plots, 4 samples of grain weighing 4-5 kg were taken from each repetition. In the end, each variant was presented with 8 repetitions, which made it possible to carry out a full statistical data processing and make a variance analysis with the identification of influence strength of the studied factors: agricultural background (factor A); varieties (factor B), and moisture degree of the growing season (factor C). Statistical processing was carried out in Microsoft Excel.

Biochemical analysis of grain quality was carried out in the analytical laboratory of the Federal Research Center Tyumen Scientific Center SB RAS (FITC TyumSC SB RAS). The protein content was determined by Kjeldahl (10846-91); fat – in a Soxlet apparatus (GOST 29033-91); starch – on a polarimeter (GOST 10845-98). Mathematical processing of the obtained results was carried out according to the standard methodology using the Microsoft Excel software product.

Electrophoresis of spare alcohol-soluble grain proteins was carried out in the laboratory of genomics research in crop production of the Federal Research Center “Tyumen Scientific Center” of the Siberian branch of the Russian Academy of Sciences according to the previously described method [11].

The growing season of 2020 can be characterized as warm and moderately dry. The amount of precipitation from May to August was 189 mm, which is 78% of the norm (Figure 1). In the second decade of May, significant precipitation fell. This ensured optimal moistening of the arable horizon and contributed to the rapid emergence of oat seedlings. In the third decade of June, there were heavy rains again, which favorably affected the development of oats in the phase of ear formation and flowering. They also provided moisture to grain crops during the grain filling period. Maturation took place in low precipitation and elevated temperature.

The growing season of 2021 can be characterized as hot and acutely arid, with manifestation of atmospheric and soil drought from April to September. Seedlings of grain crops appeared much later. They were uneven. Tillering and flowering took place in the absence of moisture in the arable horizon at very high temperatures. Maturation was delayed due to a decrease in temperature against the background of moisture deficiency.
3. Results and Discussion

At the natural agricultural background, where mineral fertilizers have not been applied for 25 years, the yield of the studied varieties significantly differed. This indicates the varietal characteristics of oat of West Siberian breeding. In 2020, the maximum grain harvest was for the Otrada variety – 2.13 t/ha (Table 1). Under the same conditions, the Foma variety formed a yield 14% lower, with the smallest significant difference – 0.07 t/ha. The Talisman variety, which was bred by breeders earlier than Otrada and Foma, significantly lost to them. The yield of the Talisman in 2020 was equal to 1.6 t/ha, being inferior 33 and 17% to Otrada and Foma, respectively. In the hot year 2021, the yield under control decreased, but the nature of varietal responsiveness remained the same. The maximum harvest was for the Otrada, the minimum was for the Talisman.

Table 1. Yield of varieties of oats sown at different levels of agricultural background.

| Varieties | Years* | Agricultural background level |
|-----------|--------|------------------------------|
|           |        | Natural (w/o fertilizers)    | Medium (N_{60}P_{20}) | Elevated (N_{90}P_{40}) | High (N_{150}P_{60}) | Very high (N_{200}P_{80}) |
| Talisman  | 2020   | 1.60                          | 3.45                  | 4.31                     | 5.47                     | 5.62                     |
|           | 2021   | 1.22                          | 2.54                  | 2.63                     | 2.47                     | 2.30                     |
| Otrada    | 2020   | 2.13                          | 3.32                  | 4.72                     | 6.30                     | 6.16                     |
|           | 2021   | 1.58                          | 3.14                  | 3.24                     | 3.24                     | 3.11                     |
| Foma      | 2020   | 1.87                          | 3.64                  | 4.94                     | 6.44                     | 5.78                     |
|           | 2021   | 1.59                          | 3.13                  | 3.19                     | 3.36                     | 3.36                     |

The average error is 0.05; the accuracy of the experiment is 1.43%; the difference error is 0.07

*Student’s criterion - 2; the smallest significant difference (SSD) - 0.07

* - 2020 - moderately moist, warm
- 2021 - very dry, hot

The application of mineral fertilizers at a dose of N_{60}P_{20} kg/ha of the active substance ensured the planned yield of 3.0 t/ha of grain. In this variant, the Foma variety stood out, the yield of which was maximum – 3.64 t/ha. This fact indicates that the use of the commonly accepted nutritive efficiency from soil and fertilizers in Western Siberia does not guarantee the accuracy of obtaining yields of the Foma oat variety. Therefore, it is necessary to further develop a varietal system of fertilizers with the identification of each normative indicator for the variety.

The Talisman variety responded well to the medium level of the agricultural background, the yield of which was 3.45 t/ha, which also confirms our point of view about the development of a varietal
fertilizer system and its inclusion in the variety passport. The closest to the planned yield was the Otrada variety – 3.32 t/ha.

The lack of moisture in the soil throughout the growing season (2021) showed the ambiguity of variety behaviour to drought. It is necessary to single out the varieties Otrada and Foma, which reduced the yield to 3.14 and 3.13 t/ha, but the harvest was in the range of the planned yield. This cannot be said about the Talisman variety, which during drought could not provide 3.0 t/ha. The actual yield was 2.54 t/ha.

At the increased agricultural background, which provided for a planned yield of 4.0 t/ha of oat grain, the Otrada and Foma varieties were again distinguished – grain harvest in 2020 amounted to 4.72 and 4.94 t/ha. Exceeding the planned yield by 18 and 24% proves once again that the generally accepted agrochemical indicators used in calculating fertilizer doses are not suitable for these varieties. The Talisman variety in the same year formed 4.31 t/ha, which is 7% higher than the plan. This is acceptable and confirms that the generally accepted indicators: economical removal, nutrient efficiency from soil and fertilizers are suitable for the Talisman variety.

In the acutely arid 2021, instead of the planned yield of 4.0 t/ha, the studied varieties crop at the level of the previous variant. This is due to the fact that soil moisture reserves were sufficient to form only for such a quantity of grain.

At the high agricultural background, where N$_{150}$P$_{60}$ kg/ha was introduced, the yield of the Otrada and Foma varieties in 2020 reached the maximum level according to experiment – 6.30 and 6.44 t/ha, respectively. The yield of the Talisman was slightly lower, but within the plan – 5.47 t/ha. Consequently, the studied varieties can be characterized as high-intensity, having a high yield potential. In the acutely arid year of 2021, there was no tendency to decrease yields relative to previous variants – it remained at the level of 2.47-3.36 t/ha.

The most interesting option remains with a very high agricultural background, where 200 kg of nitrogen and 80 kg of phosphorus were introduced. For Western Siberia, these are quite high doses and available only to large farms, for which the priority is not the economy, but the gross yield of grain, for example, livestock enterprises or poultry farms [12, 13].

In 2020, which was relatively favorable for growing oat, only the Otrada variety – 6.16 t/ha - maintained yields at a very high agricultural background. The Talisman did not reach the planned yield of 6.0 t/ha. Its yield amounted to 5.62 t/ha or 94% of the plan. This gives us the right to believe that the varietal limit of the Talisman in the conditions of the forest-steppe of the Trans-Urals is 5.5 t/ha and higher yields can be obtained only with a combination of favorable weather conditions and an individually selected fertilizer system. The yield of the Foma variety at a very high agricultural background corresponded to the planned 5.78 t/ha at least significant difference of 0.07 t/ha.

In 2021, where only 40% of precipitation norm fell in the period from May to August, high doses of fertilizers often had a negative effect, expressed in a decrease in yields relative to lower levels of agricultural background. We noted such an effect only in the Talisman variety, the yield of which decreased from 2.47 to 2.30 t/ha relative to the previous variant (high agricultural background). A certain tendency to lower yields was also noted in the Otrada variety, but to a lesser extent than in the Talisman. The yield of the Foma variety remained at the same level – 3.36 t/ha.

Protein content is considered one of the main biochemical indicators characterizing grain quality. Its content depends on external factors – weather, moisture, and agricultural background level. The maximum protein content in the grain is limited by variety genetics [14].

Leached chernozem, on which experiments with fertilizers were carried out, is characterized by a very low supply of nitrate nitrogen in the period from oat sowing to panicle formation – the nitrate content in the arable layer does not exceed 8 mg/kg [12]. Therefore, grain crops on a natural agricultural background, without the introduction of mineral fertilizers, develop in conditions of nitrogen nutrition deficiency. Protein formation on such soils is mainly due to the genetic characteristics of the variety [15].

In 2020, the grain of the Talisman variety contained 6.1±0.5% protein (table 2). The intra-field coefficient of variation was 8%, which corresponded to a low degree of variability. In the acutely arid
year of 2021, yields were lower, which led to some improvement in nitrogen nutrition. This had a positive effect on the protein content in the grain – 7.5% with a significant decrease in the variability of values for the variant. The Otrada variety was initially distinguished by a higher protein value in the grain. Its content in 2020 and 2021 was the same – 7.0±0.7 and 7.3±0.5%, respectively. There was higher intra-field variability. Foma, as noted above, was inferior to Otrada in yield at the natural agricultural background, but in 2020 had no significant differences in the protein content in the grain. In the acutely arid year of 2021, this variety stood out with a minimum value among the studied varieties – 6.4% with the least significant difference of 0.48%.

Table 2. Protein content in oat grain at different levels of agricultural backgrounds, %.

| Varieties | Years | Agricultural background level | Natural, w/o fertilizers | Medium (N_{90}P_{20}) | Elevated (N_{90}P_{60}) | High (N_{150}P_{60}) | Very high (N_{200}P_{60}) |
|-----------|-------|-------------------------------|--------------------------|-----------------------|------------------------|----------------------|--------------------------|
|           |       | x±σ CV                        | x±σ CV                   | x±σ CV                | x±σ CV                | x±σ CV              | x±σ CV                  |
| Talisman  | 2020  | 6.1±0.5 8                     | 6.5±1.0 15               | 7.7±0.6 7            | 8.4±0.3 4            | 7.2±0.6 8          |
|           | 2021  | 7.5±0.2 3                     | 8.6±0.3 4               | 9.6±0.3 3            | 9.5±0.2 2            | 10.6±0.2 2         |
| Otrada    | 2020  | 7.0±0.7 10                    | 6.9±0.4 5               | 9.0±0.7 8            | 10.4±0.3 3           | 9.9±0.7 7          |
|           | 2021  | 7.3±0.5 7                     | 7.6±0.4 5               | 9.9±0.4 4            | 11.0±0.6 6           | 10.5±0.2 2         |
| Foma      | 2020  | 6.7±0.1 2                     | 7.5±0.3 4               | 8.9±0.6 7            | 11.2±0.6 5           | 11.6±0.3 2         |
|           | 2021  | 6.4±0.2 4                     | 8.2±0.7 8               | 9.8±0.2 2            | 11.5±0.3 3           | 11.8±0.5 4         |

The average error is 0.17; the accuracy of the experiment is 1.93%; the difference error is 0.24
Student's criterion - 2; the smallest significant difference (SSD) - 0.48
x - the arithmetic mean; σ - the standard deviation; CV - the coefficient of variability
2020 - moderately moist, warm; 2021 - very dry, hot

The introduction of increasing doses of fertilizers to the level of a high agricultural background ensured a stable increase in the protein content in grain both in 2020 and 2021. Nevertheless, genetic features began to manifest. Thus, in the Talisman grain, the protein content did not exceed 8.4-9.5%, which was the minimum value in the experiment. Varieties Otrada and Foma, when fertilizing in doses of N_{90}P_{20}; N_{90}P_{60}; N_{150}P_{60} kg/ha of the active substance, formed grain with a significantly higher protein content. At a high agricultural background, its content reached 10.4-11.5% with variation coefficient of up to 6%. With a further increase in the mineral nutrition level (very high agricultural background), the protein content in the grain of the studied varieties did not change under different weather conditions – all deviations were within the limits of experimental error and were less than the least significant difference. During the experiment, a positive correlation (r=0.78) was established between the nitrogen fertilizers applied and the protein content in oat grain. The genetic potential of the studied oat varieties was also determined: Talisman – 6.1-9.5%; Otrada and Foma – 6.4-11.5%. In contrast moisture conditions, the varieties Otrada and Foma showed stability in protein accumulation, while the Talisman reacted to the weather conditions of the growing season.

During the experiments, it was found that fat content in oat grain also depends on the variety (Table 3). In 2020, the fat content of Talisman grain was 3.8±0.1% with a very low variation coefficient (CV=3%). The remaining varieties were characterized by a higher content: Otrada – 5.4±0.2%; Foma – 4.3±0.2%. Since the varieties were grown in the same field, the probability of the effect of weather conditions and the level of mineral nutrition is excluded. In 2021, when there was a very strong shortage of moisture in the soil and the weather was hot, the fat content in oat grain did not significantly change relative to the previous year. The differences were only due to varietal characteristics.

The application of mineral fertilizers in various doses, up to the creation of a very high agricultural background, did not affect the fat content in the grain of the studied oat varieties. The intra-field
variability was very low – the variation coefficient by variants and years of research did not exceed 10%, which indicates the stability of the fat content in oat grain.

**Table 3.** Fat content in the grain of oat varieties with different agricultural background, %.

| Varieties | Years | Natural, w/o fertilizers | Medium (N\textsubscript{60}P\textsubscript{20}) | Elevated (N\textsubscript{90}P\textsubscript{60}) | High (N\textsubscript{150}P\textsubscript{60}) | Very high (N\textsubscript{300}P\textsubscript{60}) |
|-----------|-------|--------------------------|---------------------------------|---------------------------------|---------------------------------|---------------------------------|
| Talisman  | 2020  | 3.8±0.1                  | 4.1±0.2                        | 4.1±0.1                         | 4.2±0.2                         | 4.1±0.2                         |
|           | 2021  | 4.0±0.1                  | 4.2±0.2                        | 4.1±0.1                         | 4.1±0.1                         | 4.2±0.2                         |
| Otrada    | 2020  | 5.4±0.2                  | 5.7±0.3                        | 5.9±0.4                         | 5.9±0.4                         | 5.9±0.3                         |
|           | 2021  | 5.8±0.2                  | 6.3±0.4                        | 6.5±0.1                         | 5.9±0.2                         | 5.7±0.4                         |
| Foma      | 2020  | 4.3±0.2                  | 4.2±0.1                        | 4.4±0.2                         | 4.5±0.2                         | 4.5±0.2                         |
|           | 2021  | 4.4±0.0                  | 4.5±0.1                        | 4.6±0.2                         | 4.5±0.1                         | 4.5±0.1                         |

The average error is 0.0 7; the accuracy of the experiment is 1.64%; the difference error is 0.11 Student’s criterion - 2; the smallest significant difference (SSD) - 0.22 

x - the arithmetic mean; σ - the standard deviation; CV - the coefficient of variability 2020 - moderately moist, warm; 2021 - very dry, hot

Another biochemical indicator of grain crops is the starch content, which characterizes the availability of carbohydrates in commercial products [16]. It was found that the oat grain, which was grown on a natural agricultural background, contained from 42.9 to 47.2% of starch. When analyzing Table 4, a certain dependence of the effect of weather conditions and the level of agricultural background is traced. In a favorable 2020, the starch content in Talisman grain was equal to 46.6 ± 1.2%. In 2021, this indicator did not have a significant difference, which indicates the relative stability of the variety with a shortage of nutrients in the soil. When applying fertilizers at a dose of N\textsubscript{60}P\textsubscript{20} kg/ha (the medium level of the agricultural background), the starch content did not change in different weather years. When creating increased agricultural background (N\textsubscript{90}P\textsubscript{60}), there was a significant decrease in starch in Talisman grain in an acutely arid year. A further increase in the doses of mineral fertilizers again ceased to affect the starch content in the grain.

In the varieties Otrada and Foma, the starch content was characterized by a clear dependence on the level of nutrition and weather conditions. Fertilization in 2020 reliably provided an increase in the starch content from 48.4 to 59.1% in the grain of the Otrada variety, and in Foma – from 45.5 to 54.8%. With a shortage of soil moisture and hot weather, the starch content in the grain of the Otrada variety significantly decreased to 42.9-45.9%, and in the Foma variety – 44.7-47.2%. It was found that in an acutely arid year, the effect of fertilizers on the starch content in these varieties is insignificant.

The ratio of starch to protein is considered a qualitative indicator of the biochemical composition of grain. The optimal ratio for cattle ration is 0.12-0.18 units. A higher value indicates an imbalance of the feed and requires diet adjustment [17]. The grain of the studied oat varieties was characterized by a wide range of starch-protein ratio. Growing oat on a natural and medium agricultural background produced grain with a ratio of 0.13-0.18 units without identifying varietal characteristics and weather conditions. The increased agricultural background, which was designed to obtain the planned yield of 4.0 t/ha of grain, provided the optimum ratio of starch to protein in the studied varieties in a favorable 2020 year. In the conditions of an acutely arid year, this ratio increased to 0.22 units, due to an increase in the protein content.
Table 4. Starch content in oat grain at different agricultural background, %.

| Varieties | Years | Natural, w/o fertilizers | Medium (N\textsubscript{90}P\textsubscript{60}) | Elevated (N\textsubscript{90}P\textsubscript{60}) | High (N\textsubscript{150}P\textsubscript{60}) | Very high (N\textsubscript{200}P\textsubscript{60}) |
|-----------|-------|--------------------------|-----------------|-----------------|-----------------|-----------------|
|           |       | x±σ                      | CV              | x±σ             | CV              | x±σ             | CV              |
| Talisman  | 2020  | 46.6±1.2                 | 3               | 49.4±3.5        | 7               | 51.6±3.9        | 8               | 47.5±1.2        | 2               | 46.1±0.6        | 1               |
|           | 2021  | 45.4±0.5                 | 1               | 48.3±4.8        | 10              | 42.9±0.6        | 1               | 45.3±0.9        | 2               | 46.9±1.5        | 3               |
| Otrada    | 2020  | 48.4±1.0                 | 2               | 49.2±0.7        | 1               | 56.9±2.5        | 4               | 59.1±1.8        | 3               | 58.1±4.3        | 7               |
|           | 2021  | 42.9±0.6                 | 1               | 43.3±0.7        | 2               | 45.9±1.1        | 2               | 43.0±0.9        | 2               | 42.5±0.7        | 2               |
| Foma      | 2020  | 45.5±2.4                 | 5               | 49.0±2.4        | 5               | 52.4±2.4        | 5               | 54.8±1.2        | 2               | 52.6±1.6        | 3               |
|           | 2021  | 47.2±2.7                 | 6               | 46.8±1.3        | 3               | 44.7±1.1        | 2               | 46.5±2.4        | 5               | 48.7±2.0        | 4               |

The average error is 0.74; the accuracy of the experiment is 1.53%; the difference error is 1.04
Student's criterion - 2; the smallest significant difference (SSD) - 2.08
x - the arithmetic mean; σ - the standard deviation; CV - the coefficient of variability
2020 - moderately moist, warm; 2021 - very dry, hot

Talisman and Otrada, which grain in 2020 had an optimal ratio of starch to protein, showed positive results at the high agricultural background. In an acutely arid year, the studied varieties at high agricultural background did not form grain with optimal characteristics from the point of view of zootechnics. Thus, the following conclusion can be drawn: when growing oat for cattle, it is necessary to adhere to the medium and increased level of agricultural background, which provides the planned yield of oat 3.0 and 4.0 t/ha of grain, respectively.

Conducting a comprehensive field experiment made it possible to identify the strength of each factor effect and their interaction. It was found that the yield of the studied oat varieties by 48.5% depends on agricultural background level and by 32.9% on the weather conditions of the growing season. A small part of the variety effect on yield formation is due to the fact that Talisman, Otrada and Foma are similar in genotype to each other. They were bred at about the same time and the author of these varieties is Fomina Maria Nikolaevna, a leading researcher at the laboratory of breeding of grain crops of the Federal Research Center Tyumen Scientific Center SB RAS. The analysis of the component composition ofavenins by electrophoresis confirms the proximity of these varieties. The formula of the Talisman variety avenin has the form Avn A4 B4 C2, the Otrada variety is Avn A10+11 B4 C8, and the Foma variety is Avn A11 B8 C8. As can be seen from the protein formulas of avenin, the same alleles of the avenin-coding loci – A11, B4 and C8 - were identified for the studied varieties. That is, for several decades, varieties with a certain combination of avenin-coding loci alleles have been created for cultivation in the region. Biochemical markers, including oat avenins, are subject to selection, as a result of which genotypes with a stable combination of genes – adaptive gene complexes - are created under certain environmental conditions. At the same time, the adaptive characteristics of populations correspond to the common locally spread alleles marking them, which are of the greatest value from a practical point of view [18]. The presence of identical alleles of avenin-coding loci in the studied varieties not only indicates their genetic proximity, but also may indicate the coupling of these alleles with valuable economic and adaptively significant traits that give advantages to the genotypes bearing them in the natural and climatic conditions of Western Siberia.

The interaction of factors such as agricultural background and weather conditions is significantly lower and amounts to 13.7. The rest of the interaction is significant, but insignificant in comparison with the share of the influence of factors A and C.
According to the fat content in the grain, a varietal feature was revealed – the share of the influence of this factor (B) is 88.9%, which indicates the stability of varieties according to this indicator. Other factors and their interactions are insignificant and can be ignored. With regard to the starch content in oat grain, a high degree of effect of weather conditions was revealed – 36.1%. Mineral fertilizers have significantly less impact than the weather. Their influence rate is 7.0%. It was also revealed that the starch content in the studied oat varieties can change under the effect of weather conditions – the degree of their interaction (factor BCS) is 14.1%. Slightly less is the combined effect of fertilizers (factor A) and weather conditions (factor C) – 9.7%. This fact indicates that breeders, when creating new oat varieties, need to pay close attention to the genetic resistance of varieties to various weather conditions.

The protein content, for which oat is primarily valued as a fodder crop, depends on the level of the agricultural background by 63.6%. Therefore, this indicator is easily regulated by technological methods of cultivation. The effect of the variety and the weather is the same – the indicator of the power of influence is 7.6-7.7%, which is reliable, but insignificant.

Table 5. Indicator of the strength of the influence of the studied factors on the yield of oats and biochemical parameters of grain, %.

| Source of variation               | Oats yield | Fat     | Starch | Protein |
|----------------------------------|-----------|---------|--------|---------|
| Factor A (agricultural background)| 48.5      | 1.1     | 7.0    | 63.6    |
| Factor B (Variety)               | 3.3       | 88.9    | 3.4    | 7.6     |
| Factor C (weather conditions)    | 32.9      | 0.8     | 36.1   | 7.7     |
| AV interaction                   | 0.6       | 1.1     | 7.1    | 8.6     |
| AC interaction                   | 13.7      | 1.0     | 9.7    | 1.1     |
| BC interaction                   | 0.1       | 0.4     | 14.1   | 3.9     |
| ABC interaction                  | 0.6       | 0.5     | 6.3    | 1.2     |

The studied varieties are characterized by low responsiveness to the combination of the agricultural background level (factor A) and weather conditions (factor C). There is also a very low power of influence of the complex interaction of fertilizers, varieties, and weather. This gives us the right to believe that the protein content in the varieties of West Siberian breeding is better regulated by the agricultural background level. This makes it possible to neutralize the effect of weather conditions when growing various oat varieties in Western Siberia.

4. Conclusions
In the course of research, it was established that oat varieties of West Siberian breeding (Talisman, Otrada, Foma) have high genetic resistance to adverse weather conditions. In conditions of acute moisture deficiency during the entire growing season, grain harvest of up to 3.36 t/ha was formed, and in a favorable year, the grain harvest exceeded 6.0 t/ha. It has been proven that the fat content in oat grain is a varietal feature – the indicator of power of influence is 88.9%. The starch content in oat grain is influenced by weather conditions, but varieties react to them to varying degrees – the indicator of power of influence between variety and weather conditions is 14%. As experiments have shown, the protein content in grain can be regulated by changing the level of mineral nutrition – the indicator of power of influence of 63.6%. When breeding oat for various purposes (animal feed or cereal production), it is recommended to pay attention to the creation of varieties with a high fat and starch content.
Acknowledgments
The work was carried out according to the state task No. 122011300103-0 and with the support of the world-class West Siberian Interregional Scientific and Educational Center.

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