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Protein nitrogen as an indicator of determining the degree of stress in oats during soil drought

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Abstract. **The purpose** is to studying the response of oats to soil drought by the degree of change in the content of protein nitrogen in the leaves and identifying the most drought-resistant varieties for the breeding process. **Methods.** In the experiment, 40 varieties of oats were used, for which soil drought during tillering and flowering was artificially modeled. Determination of protein content in oat leaves was carried out on the twelfth day after the cessation of irrigation, using the Bradford reagent. **Results.** The reaction of oats to soil drought in the critical phases of ontogeny (tillering and flowering), expressed as a change in the protein content in the vegetative parts, was studied. On average for the collection, the protein content in tillering was 13.6 %, varying from 10.3 to 16.9 %. In flowering, this indicator decreased to 6.6–14.4 %. It was established that soil drought during the tillering period had a minimal impact on the varieties Assol', Novosibirskiy 5, Ulov, KROSS, Fakel, Sig, Privet, Megion, Barguzin and Argument. The decrease in protein content in these varieties varied from 7.4 to 10.8 %. In the varieties Pesets, Uran, L'govskiy, Bulanyy, Tigrovyy, Ekspress, Dedal, Narymskiy 943, Pokrovskiy 9, Rovesnik and Borets, soil drought during tillering led to a decrease in the protein content in the leaves by 20.4–30.8 %. The varieties Sig, Ulov, KROSS, Chizh, Novosibirskiy 5, Megion and Fakel were the most resistant to drought during flowering. During the analysis of the data obtained, it was revealed that the varieties L'govskiy 82, Privet, Peredovik, Assol', Ulov, Novosibirskskiy 5, and Sig reacted to a minimum degree to drought during tillering and flowering. **Scientific novelty.** The response to drought for 40 oat genotypes was established and the relationship between protein content and plant biomass was determined by the beginning of harvesting. The most promising genotypes for breeding drought-resistant oat varieties have been identified.
Keywords: stress, abiotic factors, soil drought, genotype, protein, biomass, selection process, drought tolerant cultivar.

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Белковый азот как показатель определения степени стресса овса при почвенной засухе

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Аннотация. **Цель** – изучение реакции овса на почвенную засуху по степени изменения содержания белкового азота в листьях и выявление наиболее засухоустойчивых сортов для селекционного процесса. **Методы**. В опыте использовали 40 сортов овса, для которых искусственно моделировали почвенную засуху в кущение и цветение. Определение содержания протеина в листьях овса проводили на двенадцатые сутки

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после прекращения полива с использованием реактива Бредфорда. **Результаты**. Была изучена реакция овса на почвенную засуху в критичные фазы онтогенеза (кущение и цветение), выраженная в изменении содержания протеина в вегетирующих частях. В среднем по коллекции содержание протеина в кущение составило 13,6 % при варьировании от 10,3 до 16,9 %. В цветение данный показатель уменьшался до 6,6–14,4 %. Установлено, что почвенная засуха в период кущения оказала минимальное воздействие на сорта Ассоль, Новосибирский 5, Улов, КРОСС, Факел, Сиг, Привет, Мегион, Баргузин и Аргумент. Снижение содержания протеина у этих сортов варьировало от 7,4 до 10,8 %. В сортах Песец, Уран, Льговский, Буланый, Тигровый, Экспресс, Дедал, Нарымский 943, Покровский 9, Ровесник и Борец почвенная засуха в кущение привела к снижению содержания протеина в листьях на 20,4–30,8 %. Наиболее устойчивыми к засухе в цветение были сорта Сиг, Улов, КРОСС, Чиж, Новосибирский 5, Мегион и Факел. В ходе анализа полученных данных было выявлено, что сорта Льговский 82, Привет, Передовик, Ассоль, Улов, Новосибирский 5 и Сиг в минимальной степени реагировали на засуху в кущение и цветение. Научная новизна. Установлена реакция на засуху для 40 генотипов овса и определена взаимосвязь между содержанием протеина и биомассой растений к началу уборочных работ. Выявлены наиболее перспективные генотипы для селекции засухоустойчивых сортов овса.

Ключевые слова: стресс, абиотические факторы, почвенная засуха, генотип, протеин, биомасса, селекционный процесс, засухоустойчивый сорт.

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Introduction

The development of agriculture in the conditions of global warming should follow the path of creating new drought tolerant varieties. Currently, farmers are already using wheat and barley varieties that can form a high yield with soil moisture shortage. In regions where soil and atmospheric droughts have become annual, switching to drought tolerant varieties is the only possible way to preserve agriculture. This has already been proven by science and confirmed by practice. Nevertheless, it must be recognized that the selection of drought tolerant grain varieties is at a high level only in the case of wheat and barley – this is evidenced by a large number of scientific publications in domestic and foreign literature. For oats, which is of no less national economic importance, the situation is somewhat different. The creation of oat drought tolerant varieties began relatively recently compared to wheat and barley. The reason for this is the widespread opinion that oat is a culture not demanding of growing conditions [1, p. 40]. Also, the traditional area of its cultivation is located in areas of moderate and sufficient moisture. Therefore, drought tolerant varieties of oat were unclaimed. Currently, the attitude towards oat has begun to change. Due to the unique biochemical composition of grain, oat has become an integral component of the diet of farm animals and birds [2, p. 52]. Therefore, in areas where animal husbandry and poultry farming are developed, oat crops are steadily expanding, but not due to the reduction of crops of other grain crops, but due to the involvement of new lands in agricultural turnover.

The breeding drought tolerant crops is a rather complicated process. This is due to the complexity of studying the plant's response to soil moisture deficiency, since the stress caused leads to disruption of biochemical and physiological processes at the cellular level. In this regard, plant responses to soil drought have been studied, which can both lead to the death of the plant and mobilize its forces to form a higher yield. After all, the synergistic effect and its opposite manifestations, which can affect the productivity of plants.

One of the biochemical indicators of the reaction of plants to stress caused by a critical soil moisture shortage is the protein nitrogen content in the vegetative parts. Unfavorable conditions in which plants develop disrupt the biochemical cycle of protein synthesis and its derivatives – amino acids and peptides. Also, it was found that under the effect of moisture deficiency in plant cells, the process of destruction of previously formed protein substances can begin, which negatively affects the development of plants, as well as the formation of the crop and its quality [3, p. 10; 4, p. 4]. Unlike other indicators, the protein content in plant leaves has a pronounced effect of prolonged aftereffect of any negative factors, including soil droughts.

Researches by G. A. Batalova, I. G. Loskutov, et. al. established a close positive correlation between the protein content in leaves and the yield of grain crops [5, p. 10; 6, p. 59; 7, p. 32; 8, p. 53]. Therefore, this indicator is promising for determining the degree of manifestation of the soil drought negative impact and forecasting the yield of grain crops that have fallen under soil drought.

The content of protein nitrogen in the vegetative parts of plants, especially in the leaves, is an indicator that depends not only on external factors, but also on

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the genotype [9, p. 49]. Therefore, the decrease degree in its content caused by soil drought serves as an indirect indicator of the genotype's drought tolerance and can become a criterion for selecting promising parent forms when creating new varieties that are resistant to soil droughts [10, p. 9; 11, p. 10].

The objective of the research is to study the oat reaction to soil drought by the degree of change in the content of protein nitrogen in the leaves and to identify the most drought tolerant varieties for the breeding process.

Methods

The vegetative experience in studying the effect of soil drought on oats was laid on the basis of the Research Institute of Agriculture of the Northern Trans-Urals – a branch of the Tyumen Scientific Center of the Siberian Branch of the Russian Academy of Sciences. The scientific and technical base of the Institute is located in the forest-steppe zone of the Trans-Urals. The studies were conducted in a greenhouse without artificial lighting and heating in the period from April to August in 2020–2022. Ventilation in the greenhouse was carried out by the free movement of air masses through the windows. The object of the study was 40 varieties of oats (*Avena sativa* L.) of Russian breeding. The seed material was taken from the collection of the Northern Trans-Urals Research Institute, which is grown in the same type of soil and climatic conditions. All seeds were calibrated before sowing – small and very large ones were culled. The list of oat varieties for conducting an experiment on the effects of soil drought is presented in Table 1.

Before sowing, the seed material was treated with Lamador protectant in doses recommended by the manufacturer – 0.02 ml per 100 grams of grain, which corresponded to 0.2 liters per ton of grain [12, p. 108].

Oats were grown in boxes with a volume of 24 liters and dimensions of 40 × 30 and a height of 20 cm. As a soil, ordinary earth taken from the arable layer of the experimental field of the Northern Trans-Urals Research Institute was used. The soil substrate was characterized by a medium-loamy silty-dusty granulometric composition. Agrochemical and physico-chemical properties of the soil corresponded to the gray forest soil of the Northern Trans-Urals [13, p. 834; 14, p. 489].

In the process of preparing the soil, fertilizers were applied at a dose of $N_{60}P_{20}$ kg/ha, which in the conditions of the forest-steppe zone of the Trans-Urals is enough to form a yield of 3.0 t/ha [15, p. 35; 16, p. 37]. Fertilizers were mixed with the soil before laying them in boxes. For irrigation, ordinary tap water with a pH of 7.6 and an electrical conductivity of 20.00 mSm/m was used. Saturation was carried out to the level of 80% of the lowest moisture capacity (80 % of field moisture capacity. Within 5 days, the water was distributed over the soil voids, which was compacted to an equilibrium state of 1.2 g/cm^3.

30 seeds were sown in boxes, to a depth of 7 cm. After 5 days, the ascended plants were counted and the plants lagging in growth were removed. Two weeks later, the seedlings were re-examined, after which 25 well-developed plants were left. This corresponded to the standard oat density of 200 pcs/m^2 by the beginning of harvesting.

Table 1

Oat grades participating in the experiment to study the impact of soil drought (2020–2022)

No.	Grade	Cultivar	No.	Grade	Cultivar
1	Yubilyar	mutica	21	Pesets	mutica, aristata
2	Barguzin	mutica	22	Borets	mutica
3	Oven	mutica	23	Dedal	mutica, aristata
4	Avatar	aurea	24	Orion	mutica
5	Faust	mutica	25	Talisman	mutica
6	Assol'	mutica	26	Pokrovskiy 9	aristata
7	Desant	aristata	27	Vilenskiy	mutica
8	Gorizont	mutica	28	KROSS	mutica
9	L'govskiy 82	mutica	29	Taezhnik	aurea
10	ZALP	mutica, aurea	30	Narymskiy 943	mutica
11	Privet	aurea	31	Chernigovskiy 83	aurea
12	Novosibirskiy 5	mutica	32	Tigrovyy	cinerea
13	Fakel	aristata	33	Peredovik	brunnea
14	Irtysh 13	mutica	34	Ekspress	cinerea
15	Egorych	obtusata	35	Sig	aristata
16	Argument	aristata	36	Megion	mutica
17	Rovesnik	obtusata	37	Konkur	mutica
18	Chizh	aurea	38	Bulanyy	mutica
19	Tubinskiy	mutica	39	Uran	aristata
20	L'govskiy	mutica	40	Ulov	mutica

Table 2

Protein content in oat leaves under stress from soil drought, % of air-dry weight, 2020–2022

Genotypes	Tillering		Flowering	
	Control	Drought	Control	Drought
Yubilyar	12.2 ± 0.6	10.4 ± 0.7	10.5 ± 0.8	8.9 ± 0.6
Barguzin	13.9 ± 0.3	12.4 ± 0.7	13.5 ± 0.3	12.0 ± 0.3
Oven	15.1 ± 0.3	13.3 ± 0.9	14.2 ± 0.3	12.2 ± 0.6
Avatar	16.9 ± 1.0	14.9 ± 1.2	15.6 ± 0.5	13.7 ± 0.7
Faust	15.5 ± 0.6	13.7 ± 1.1	14.0 ± 0.3	12.2 ± 0.8
Assol’	14.9 ± 0.8	13.8 ± 0.4	11.4 ± 0.7	10.2 ± 0.3
Desant	12.8 ± 0.7	10.4 ± 0.5	12.3 ± 0.8	10.1 ± 0.7
Gorizont	12.4 ± 0.3	10.6 ± 0.5	9.7 ± 0.8	8.3 ± 0.3
L’govskiy 82	13.9 ± 0.6	12.2 ± 0.6	12.2 ± 0.3	10.8 ± 0.4
ZALP	15.9 ± 0.6	13.4 ± 0.4	13.2 ± 0.5	11.4 ± 0.7
Privet	10.5 ± 0.3	9.4 ± 0.6	7.4 ± 0.2	6.6 ± 0.2
Novosibirskiy 5	15.5 ± 0.6	14.3 ± 0.3	14.1 ± 0.6	12.9 ± 0.4
Fakel	16.8 ± 0.7	15.2 ± 0.9	15.9 ± 0.8	14.4 ± 0.7
Irtysh 13	13.9 ± 0.5	11.6 ± 0.5	11.5 ± 0.2	9.8 ± 0.7
Egorych	13.5 ± 0.7	11.0 ± 0.8	13.2 ± 0.3	11.1 ± 0.6
Argument	14.8 ± 0.5	13.2 ± 0.4	12.8 ± 0.8	11.3 ± 0.5
Rovesnik	11.4 ± 0.5	8.3 ± 0.6	12.4 ± 0.7	9.5 ± 0.2
Chizh	13.0 ± 0.7	11.5 ± 0.8	11.1 ± 0.2	10.1 ± 0.5
Tubinskiy	12.5 ± 0.7	10.8 ± 0.7	10.8 ± 0.3	9.4 ± 0.6
L’govskiy	11.2 ± 0.5	8.7 ± 0.6	9.9 ± 0.3	7.7 ± 0.2
Pesets	10.3 ± 0.2	8.3 ± 0.5	9.0 ± 0.5	7.2 ± 0.2
Borets	14.3 ± 0.8	9.9 ± 0.3	16.1 ± 0.5	13.0 ± 0.6
Dedal	16.7 ± 0.9	12.7 ± 0.4	16.3 ± 0.8	12.6 ± 0.6
Orion	14.3 ± 0.7	12.3 ± 0.5	14.1 ± 0.5	12.3 ± 0.4
Talisman	16.4 ± 0.3	14.5 ± 0.5	14.7 ± 0.5	12.7 ± 0.3
Pokrovskiy 9	11.4 ± 0.4	8.5 ± 0.7	11.0 ± 0.2	8.9 ± 0.3
Vilenskiy	13.2 ± 0.8	11.6 ± 0.8	11.9 ± 0.3	10.5 ± 0.5
KROSS	13.7 ± 0.7	12.4 ± 0.7	10.9 ± 0.5	10.0 ± 0.4
Taezhnik	12.4 ± 0.3	10.9 ± 0.7	11.3 ± 0.5	9.8 ± 0.5
Narymskiy 943	11.6 ± 0.6	8.8 ± 0.6	11.8 ± 0.3	9.2 ± 0.4
Chernigovskiy 83	12.3 ± 0.6	10.6 ± 0.3	12.0 ± 0.8	10.3 ± 0.2
Tigrovyy	11.1 ± 0.3	8.5 ± 0.6	9.5 ± 0.8	7.4 ± 0.5
Peredovik	11.4 ± 0.4	9.9 ± 0.8	9.2 ± 0.8	8.2 ± 0.6
Ekspress	11.4 ± 0.2	8.7 ± 0.4	9.2 ± 0.7	7.4 ± 0.3
Sig	16.7 ± 0.4	15.0 ± 0.5	15.0 ± 0.3	13.8 ± 0.5
Megion	15.1 ± 0.4	13.5 ± 0.5	14.4 ± 0.6	13.1 ± 0.5
Konkur	12.9 ± 0.6	10.6 ± 0.9	10.1 ± 0.4	8.7 ± 0.2
Bulanyy	13.5 ± 0.3	10.4 ± 0.8	12.1 ± 0.3	10.2 ± 0.3
Uran	14.7 ± 0.8	11.7 ± 0.6	14.2 ± 0.5	12.0 ± 0.8
Ulov	15.9 ± 0.5	14.4 ± 1.0	13.8 ± 0.3	12.7 ± 0.4

Soil drought was caused by stopping irrigation and a natural decrease in soil moisture to 30–35 % of the lowest moisture capacity. In the experiment, two drought variants were simulated – during oat tillering and during its flowering. Before the onset of these phenological phases, oats were regularly watered 1 time in 7 days. A week before the selected phenological phases (the beginning of tillering and the sweeping of oats), watering was stopped for 14 days.

As a control, plants of the same cultivar were used, grown under identical conditions, but in the absence of soil moisture shortage. Irrigation at the control was carried out weekly, preventing a decrease in humidity of less than 60 % of the field moisture capacity. As weed vegetation appeared, it was removed manually at the earliest possible stage of development to exclude the impact on oats of any factor other than soil drought. The model experiment was carried out in a three-fold repetition. All containers with oat were in the same greenhouse, which caused uniform microclimate conditions. To prevent overheating of plants and exposure to high atmospheric humidity, the greenhouse was periodically ventilated.

Determination of the protein content in oat leaves was carried out on the twelfth day after watering was stopped, when all the plants in the containers were completely in the tillering and flowering phase. The selection of plant samples was carried out in one day, immediately transferring them to the laboratory. Extraction was carried out with a phosphate buffer with a pH of 7.8. Further, the extract was subjected to centrifugation for 10 minutes at 14 thousand rpm, which ensured stable stratification and separation of the supernatant from the sediment. The infusion fluid was taken with an automatic pipette and transferred into 1.5 ml Eppendorf-type tubes. Then a phosphate buffer and Bradford reagent were added. Mixing was carried out on a Vortex V-3 (Elmi) and left at room temperature for 5 minutes for the color development. The optical density was determined on a Beckman DU® 640 spectrophotometer at a wavelength of 595 nm.

Statistical processing of the results was carried out by the variance analysis method using Microsoft Excel and Statistica 6.0 programs.

Results

The protein content in oat leaves during the tillering-tube period at the control varied in the collection from 10.3 to 16.9 %, and averaged 13.6 % (Table 2). The variability of values in the collection was equal to 14 % (Table 3), which corresponded to the average degree of diversity of protein content in oat leaves. Varieties with a minimum content of protein substances were identified: Pesets, Privet, Tigrovyy, L'govskiy, Rovesnik, Pokrovskiy 9, Peredovik, Ekspress, and Narymskiy 943. During the tillering period, the protein content in the leaves of these varieties varied from 10.3 to 11.6 %. The studied collection also identified varieties whose leaves had a protein content of more than 15 %: Oven, Megion, Faust, Novosibirskiy 5, Zalp, Ulov, Talisman, Dedal, Sig, Fakel, and Avatar. The analysis of oat characteristics presented by the authors of the varieties showed the absence of a relationship between the protein content in the leaves during tillering and the drought resistance degree. Thus, the varieties Pesets, L'govskiy, Express, and Narymskiy 943, according to the originators, do not have drought resistance, while the varieties Privet and Peredovik are drought tolerant. Nevertheless, they all fell into the group with the minimum protein content in the leaves during tillering. In the group with the maximum protein content in the leaves, there are also varieties in the characteristics of which their authors note a high degree of drought tolerance: Novosibirskiy 5, Ulov, and Sig. In the same group there was a Dedal cultivar, which is not resistant to drought.

In the later phases of oat development (flowering-grain filling), the protein content in the leaves decreased and varied from 6.6 to 14.4 % with a standard error of 0.3% and a variation coefficient of 19 %. On average, the content of protein substances in the leaves in the collection significantly decreased relative to the tillering phase ($F_{fact.} > F_{theor.}$) and amounted to 12.3 %. This is due to the beginning of the outflow of nitrogen-containing substances from the leaf apparatus to the forming grain and is a natural process for cereal plants [17, p. 86; 18, p. 13; 19, p. 58]. In the group with the minimum protein content in the leaves, the same varieties were found as they were during the tillering period – the decrease in varieties was approximately the same.

In the group of genotypes with a protein content of more than 15 % in the leaves during the flowering period, only Sig, Avatar, and Fakel were found. In addition, Borets and Dedal varieties were identified, in which the protein content in the leaves was the maximum in the collection – 16.1 and 16.3 %, respectively. These varieties, according to the statements of the originators, do not have drought tolerance at all ontogenesis stages.

Table 3

Results of analysis of variance of protein content in leaves during drought in tillering and flowering of oats

Indicators	*Tillering*		*Flowering*	
	Control	*Drought*	*Control*	*Drought*
Average	*13.6*	*11.6*	*12.3*	*10.6*
Standard error	*0.3*	*0.3*	*0.3*	*0.3*
Median	*13.6*	*11.6*	*12.1*	*10.3*
Moda	*11.4*	*10.4*	*–*	*8.9*
Standard deviation	*1.9*	*2.1*	*2.2*	*2.0*
Sample variance	*3.6*	*4.3*	*4.8*	*4.1*
Excess	*–1.0*	*–1.1*	*–0.7*	*-0.9*
Asymmetry	*0.1*	*0.1*	*0.0*	*-0.1*
Interval	*6.6*	*6.9*	*8.9*	*7.8*
Minimum	*10.3*	*8.3*	*7.4*	*6.6*
Maximum	*16.9*	*15.2*	*16.3*	*14.4*
CV, %	*14*	*18*	*18*	*19*

Note. CV is the coefficient of variation; $p < 0.05$.

The drought stress during the tillering period had quite a strong effect on the protein content in the vegetative parts of oats. The minimum decrease was recorded in the varieties: Assol', Novosibirskiy 5, Ulov, KROSS, Fakel, Sig, Privet, Megion, Barguzin, and Argument. The decrease ranged from 7.4 to 10.8 % with an average value of 15.7 % in the collection (Fig. 1).

The next group (Pesets, Uran, L'govskiy, Bulanyy, Tigrovyy, Ekspress, Dedal, Narymskiy 943, Pokrovskiy 9, Rovesnik, and Borets) was characterized by a maximum decrease in protein in leaves during soil drought during tillering. The decrease was 20.4–30.8 %, which indicates a violation of the physiological processes responsible for the synthesis of protein substances. These varieties cannot be attributed to promising parent forms when creating drought tolerant oat varieties.

In case of drought during the flowering period, the protein content in oat leaves averaged 10.6 % in the collection, varying from 6.6 to 14.4 %. The overall decrease in this indicator for the collection was equal to 14.3 % relative to the control (Fig. 2). Varieties with minimal response to soil drought during the flowering period were identified. This group includes: Sig (8.1 %), Ulov (8.2 %), KROSS (8.4 %), Chizh (8.7 %), Novosibirskiy 5 (8.8 %), Megion (9.1 %), Fakel (9.5 %). The Chizh and Sig varieties had a higher resistance to late drought.

The group of varieties most sensitive to soil drought during the flowering period were: Pesets, Narymskiy 943, Tigrovyy, L'govskiy, Dedal, and Rovesnik. The decrease in protein content in the leaves ranged from 20.1 to 23.4 %, which makes them unpromising parental forms when creating drought-resistant varieties of oats.

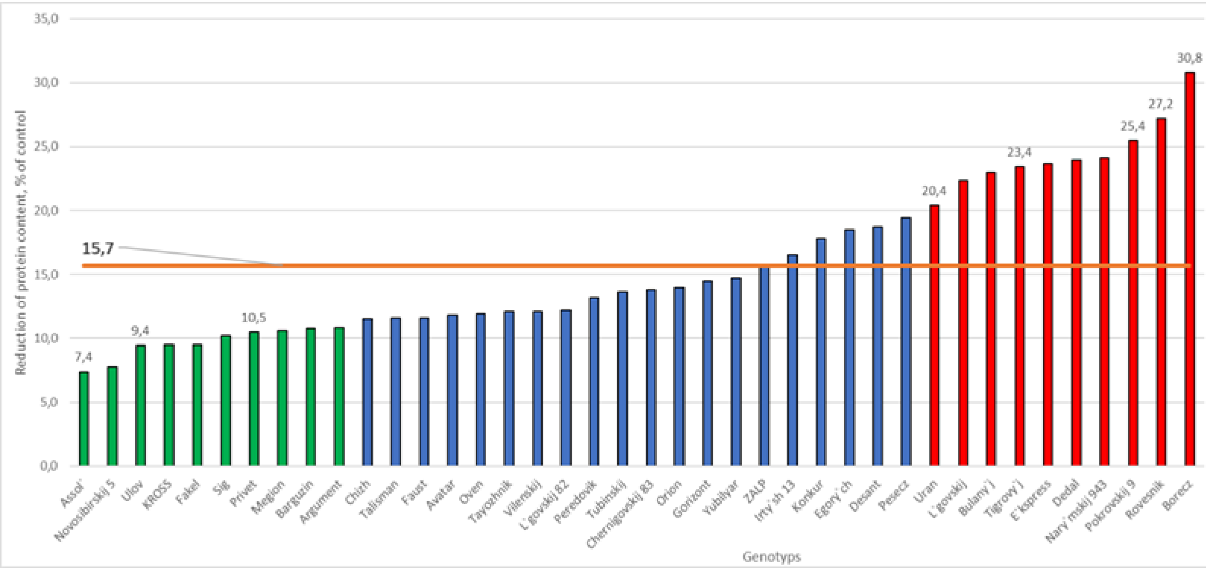

Fig. 1. Relative decrease in protein content in oat leaves during drought during tillering, % of control, 2020–2022. The red line is the average decrease in the collection

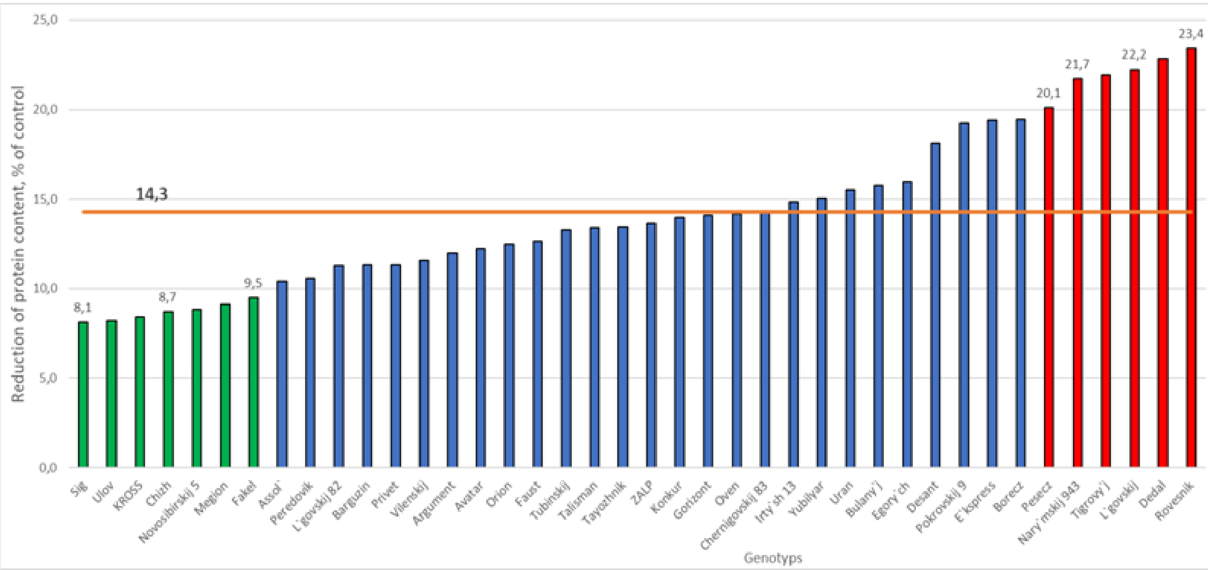

Fig. 2. Relative decrease in protein content in oat leaves during drought during the flowering period, 2020–2022. The red line is the average decrease in the collection

The biomass of the aboveground part of oats in the average collection at the control was equal to 8.4 grams, with a variation from 5.1 ± 0.2 (Chernigovskiy 83) to 15.9 ± 0.8 (Irtysh 13) grams. The degree of collection diversity by biomass of one plant was high – the variation coefficient was 27 %. The oat biomass exposed to soil drought during tillering decreased to 7.1 grams on average in the collection. The weight of one plant varied in the range from 4.4 to 13.4 grams. The calculation of the relative decrease in biomass showed that some varieties were characterized by the absence of a significant decrease under the effect of drought during the tillering period ($F_{fact} < F_{theor.}$). These varieties include: Assol', L'govskiy 82, Privet, Novosibirskiy 5, Peredovik, Sig, Ulov. Varieties with a very strong negative reaction to soil drought during tillering were also identified: Avatar, Talisman, Ekspress, Narymskiy 943, Orion, Bulanyy, Tubinskiy, and Taezhnik. Their biomass decreased by 20–26 % relative to the control.

Table 4

The mass of the above-ground part of one oat plant during drought in different periods ontogenesis (n = 10)

Varieties	***Biomass, g*** (Xav. ± ***SE)***			***Decrease, % relative to control***	
	Control (watering)	***Tillering***	***Flowering***	***Tillering***	***Flowering***
Yubilyar	*7.0 ± 0.3*	*5.7 ± 0.4*	*5.2 ± 0.3*	*18*	*25*
Barguzin	*8.4 ± 0.6*	*7.2 ± 0.3*	*7.0 ± 0.3*	*15*	*17*
Oven	*9.9 ± 0.4*	*8,4 ± 0.6*	*7.5 ± 0.5*	*15*	*25*
Avatar	*5.7 ± 0.2*	*4,6 ± 0.2*	*4.2 ± 0.2*	*20*	*26*
Faust	*8.6 ± 0.6*	*7.4 ± 0.4*	*6.9 ± 0.4*	*14*	*20*
Assol'	*9.0 ± 0.3*	*8.2 ± 0.3*	*7.7 ± 0.3*	*8**	*14**
Desant	*9.9 ± 0.6*	*8.3 ± 0.4*	*6.5 ± 0.3*	*16*	*35*
Gorizont	*6.2 ± 0.3*	*5.4 ± 0.4*	*4.8 ± 0.2*	*14*	*23*
L'govskiy 82	*12.0 ± 0.8*	*11.7 ± 0.6*	*10.2 ± 0.6*	*2**	*15**
ZALP	*8.1 ± 0.4*	*6.9 ± 0.5*	*6.4 ± 0.4*	*15*	*21*
Privet	*7.1 ± 0.3*	*6.6 ± 0.4*	*6.2 ± 0.2*	*7**	*13**
Novosibirskiy 5	*10.5 ± 0.3*	*9.5 ± 0.7*	*9.1 ± 0.5*	*9**	*13**
Fakel	*9.4 ± 0.7*	*8.3 ± 0.3*	*7.4 ± 0.2*	*12*	*21*
Irtysh 13	*15.9 ± 0.8*	*13.4 ± 0.5*	*12.3 ± 0.5*	*16*	*23*
Egorych	*6.8 ± 0.2*	*5.8 ± 0.2*	*5.2 ± 0.2*	*15*	*23*
Argument	*9.6 ± 0.4*	*8.1 ± 0.5*	*7.5 ± 0.5*	*15*	*22*
Rovesnik	*10.6 ± 0.6*	*8.7 ± 0.4*	*8.7 ± 0.4*	*18*	*18*
Chizh	*8.9 ± 0.5*	*7.6 ± 0.3*	*7.0 ± 0.2*	*15*	*22*
Tubinskiy	*6.3 ± 0.4*	*5.1 ± 0.3*	*4.9 ± 0.3*	*20*	*23*
L'govskiy	*11.9 ± 0.4*	*9.8 ± 0.4*	*7.5 ± 0.5*	*18*	*37*
Pesets	*9.7 ± 0.3*	*8.0 ± 0.3*	*7.5 ± 0.3*	*17*	*23*
Borets	*8.1 ± 0.5*	*6.8 ± 0.3*	*6.1 ± 0.4*	*16*	*25*
Dedal	*5.9 ± 0.3*	*4.8 ± 0.3*	*4.5 ± 0.2*	*18*	*24*
Orion	*9.4 ± 0.3*	*7.5 ± 0.5*	*7.3 ± 0.3*	*20*	*23*
Talisman	*6.5 ± 0.2*	*5.2 ± 0.2*	*5.0 ± 0.3*	*20*	*22*
Pokrovskiy 9	*9.5 ± 0.6*	*7.7 ± 0.3*	*6.5 ± 0.4*	*19*	*32*
Vilenskiy	*6.2 ± 0.3*	*5.4 ± 0.3*	*4.6 ± 0.1*	*12*	*26*
KROSS	*9.2 ± 0.3*	*7.8 ± 0.4*	*6.2 ± 0.4*	*15*	*32*
Taezhnik	*6.5 ± 0.4*	*4.8 ± 0.2*	*4.5 ± 0.2*	*26*	*31*
Narymskiy 943	*10.3 ± 0.4*	*8.3 ± 0.6*	*7.4 ± 0.3*	*20*	*28*
Chernigovskiy 83	*5.1 ± 0.2*	*4.4 ± 0.2*	*3.9 ± 0.1*	*15*	*25*
Tigrovyy	*5.7 ± 0.2*	*4.6 ± 0.3*	*3.9 ± 0.2*	*19*	*31*
Peredovik	*8.1 ± 0.5*	*7.5 ± 0.2*	*6.9 ± 0.4*	*8**	*15**
Ekspress	*11.1 ± 0.4*	*8.9 ± 0.4*	*7.6 ± 0.3*	*20*	*31*
Sig	*9.3 ± 0.6*	*8.5 ± 0.4*	*7.9 ± 0.3*	*9**	*15**
Megion	*5.4 ± 0.3*	*4.5 ± 0.2*	*4.0 ± 0.1*	*16*	*25*
Konkur	*9.8 ± 0.7*	*8.1 ± 0.5*	*7.6 ± 0.3*	*18*	*23*
Bulanyy	*8.1 ± 0.3*	*6.5 ± 0.3*	*5.4 ± 0.3*	*20*	*34*
Uran	*6.1 ± 0.3*	*5.0 ± 0.3*	*4.7 ± 0.3*	*18*	*22*
Ulov	*5.7 ± 0.3*	*5.2 ± 0.4*	*4.9 ± 0.2*	*9**	*14**

n – number of plants, pcs; $X_{avg.}$ *– average value; SE – standard error.*
** – differences are not significant at α=0.05,* $F_{act} < F_{theor}$.

Studies have shown that soil drought during the flowering period caused more serious damage to oat plants than its manifestation in tillering. On average, the biomass of the aboveground part before harvesting was equal to 6.5 grams with a variation ranging from 3.9 ± 0.1 (Chernigovskiy 83) to 12.3± 0.5 g (Irtysh 13). In the varieties Privet, Novosibirskiy 5, Assol', Ulov, L'govskiy 82, Sig, Peredovik there was no significant decrease in biomass ($F_{fact} < F_{theor.}$). The same varieties had a minimal reaction to soil drought during tillering, which makes them promising parental forms when breeding for drought resistance.

The most negative reaction to the soil drought during the flowering period was manifested in the varieties: Tigrovyy, Taezhnik, Ekspress, Pokrovskiy 9, KROSS, Bulanyy, Desant, L'govskiy. Their biomass has decreased by 30 percent or more under the effect of drought. It is necessary to distinguish the varieties Tigrovyy, Taezhnik, Ekspress, Pokrovskiy 9, Bulanyy, Desant, and L'govskiy, which maximally reduced biomass during drought both during tillering and flowering.

In the course of research, it was found that there is practically no correlation between the protein content in the oat leaves and the biomass – $r < 0.3$ on the Cheddock scale [20, p. 78]. This is a justification for the inefficiency of using protein content during tillering and flowering as an element of the oat yield forecast. Comparison of indicators of protein reduction in leaves and oat biomass in the stress study caused by abiotic factors is characterized by a moderate correlation – $r > 0.5$. Therefore, the identification of promising parental forms during selection for drought tolerance can be carried out based on the degree of reduction in protein content in oat leaves during tillering and flowering.

Discussion and Conclusion

To identify parent forms that are promising for the selection of drought-resistant varieties, it is possible to use an indicator of a decrease in the protein content in the leaves of plants subjected to soil drought during tillering and flowering relative to the control that does not experience a soil moisture shortage throughout the growing season. The correlation coefficient between the relative decrease in protein content and plant biomass was more than 0.5 units, which corresponds to a moderate relationship. The use of direct values of the protein content in the leaves to predict the productivity of oats has no positive effect – the correlation coefficient is less than 0.3 units.

It was found that the oat varieties: L'govskiy 82, Privet, Peredovik, Assol', Ulov, Novosibirskiy 5, and Sig minimally reduced aboveground biomass under the effect of soil drought during tillering – 2–9 % and flowering – 13–15 %. The decrease in the protein content in the leaves of these varieties was minimal – 8–13 %, which makes them promising parental forms when breeding for drought resistance.

Varieties Pokrovskiy 9, Tigrovyy, Ekspress, Bulanyy, L'govskiy reacted negatively to the manifestation of soil droughts as much as possible: the protein content in the leaves decreased by 16–22 %, and the loss of plant biomass before harvesting was 19–37 %. These genotypes are not promising in the selection of drought-resistant varieties of oats.

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