ОБЩЕЕ ЗЕМЛЕДЕЛИЕ И РАСТЕНИЕВОДСТВО/GENERAL AGRICULTURE AND CROP PRODUCTION

DOI: https://doi.org/10.60797/JAE.2025.64.12

ASSESSMENT OF THE CONDITION OF AGROPHYTOCENOSES OF WINTER WHEAT DURING THE WINTER PERIOD IN THE KALININGRAD REGION

Research article

Krasnopyorov A.G.[1, *], Troyan T.N.[2]
[1] ORCID : 0000-0002-8202-8423;
[2] ORCID : 0009-0007-7852-433X;
[1] Federal Williams Scientific Research Center of Forage Production and Agroecology, Kaliningrad, Russian Federation
[2] Kaliningrad State Technical University, Kaliningrad, Russian Federation

* Corresponding author (akras_01[at]rambler.ru)

Abstract

The scientific article contains an analysis of field studies to assess the development and overwintering of winter wheat of the Sineva variety in the Kaliningrad region. The humid climate of the region with unstable snow cover, and in recent years more often with its absence, are the main risk factors affecting the productivity of winter crops. In soil and climatic conditions, the problem of crop waterlogging is an issue often encountered in agronomic practice. In the fields, areas with perched water are locally formed during the autumn-spring growing season of winter cereals, which reduces the areas with high potential crop yields, and, in turn, affects the gross grain harvest. In this regard, monitoring of winter crops acts as a tool for predicting the productivity of agrophytocenoses. The assessment results showed that the overwintering of winter wheat in 2021–2022 and 2024–2025 on sod-weakly podzolic gleyic soils amounted to a high score and is characterized as "very high"; on sod-gley soils — from "very low" to "medium". However, under conditions of local over-moistening and formation of perched water, the physiologically healthy state of wheat plants decreases to 85–95% with over-moistening for more than 60 days, and by 55–65% — with over-moistening up to 35–40 days, by 20% — 20–25 days, respectively; these values apply for temperatures close to zero. With moderate soil moisture, an absolutely optimal state of plants under a snow cover of 12 cm, a temperature of minus 16–20 ^{0}C and soil freezing to a depth of 8-10 cm is noted. The absence of ice, ice crusts, freezing, icing of parts of winter wheat plants in such conditions is ensured by maintaining the snow cover in a loose, airy, structural form.

Keywords: winter wheat, overwintering of plants, waterlogging, tissue necrosis, soaking of crops.

ОЦЕНКА СОСТОЯНИЯ АГРОФИТОЦЕНОЗОВ ОЗИМОЙ ПШЕНИЦЫ В ЗИМНИЙ ПЕРИОД В УСЛОВИЯХ КАЛИНИНГРАДСКОЙ ОБЛАСТИ

Научная статья

Краснопёров А.Г.[1, *], Троян Т.Н.[2]
[1] ORCID : 0000-0002-8202-8423;
[2] ORCID : 0009-0007-7852-433X;
[1] Федеральный научный центр кормопроизводства и агроэкологии имени В.Р. Вильямса, Калининград, Российская Федерация
[2] Калининградский государственный технический университет, Калининград, Российская Федерация

* Корреспондирующий автор (akras_01[at]rambler.ru)

Аннотация

Анализ полевых исследований по оценке развития и перезимовки озимой пшеницы сорта Синева в условиях Калининградской области. Гумидный климат региона с неустойчивым снежным покровом, а в последние годы чаще с его отсутствием, — основные факторы риска, влияющие на продуктивность озимых. В почвенно-климатических условиях региона проблема вымокания посевов — вопрос, часто встречающийся в агрономической практике. На полях локально формируются участки с верховодкой в осенне-весенний период вегетации озимых злаков, что сокращает площади с высокой потенциальной урожайностью культуры, и, в свою очередь, отражается на валовых сборах зерна. В связи с этим мониторинг озимых посевов выступает как инструмент прогнозирования продуктивности агрофитоценозов. Результаты оценки показали, что перезимовка озимой пшеницы в 2021–2022 гг. и 2024–2025 гг. на дерново-слабоподзолистых глееватых составила высокий балл и характеризуется как «очень высокая»; на дерново-глеевых почвах — от «очень низкой» до «средней». Однако в условиях локального переувлажнения и формирования верховодки физиологически здоровое состояние растений пшеницы снижается до 85–95% при переувлажнении более 60 дней, и на 55–65% — при переувлажнении до 35–40 дней, на 20% — 20–25 днях соответственно; эти значения применимы при температуре воздуха близкой к нулю. Отмечено при умеренном увлажнении почв состояние растений под снежным покровом в 12 см, температуре минус 16–20 ^{0}C и промерзании почвы на глубину до 8–10 см находится в абсолютно оптимуме. Отсутствие льда, ледяных корок, обледенения частей растений озимой пшеницы в таких условиях обеспечено за счет сохранения снежного покрова только в состоянии рыхлой, воздушной, структурной формы снега.

Ключевые слова: озимая пшеница, перезимовка растений, переувлажнение почвы, некроз тканей, вымокание посевов.

Introduction

When cultivating agricultural crops, risks are identified that can affect the development of winter crops during the autumn-winter-spring growing season and the phytosanitary condition of agrocenoses after overwintering. These include dynamic temperature changes from positive to negative in the tillering node zone of cereals; repeated thawing and freezing of the upper soil layer; the formation of an ice crust; lack of snow cover, and, conversely, prolonged snow cover [1], [3], [5], [7].

Additionally, among the limiting risk factors in the region for cultivating winter crops is the water regime of the soils. A deficiency or excess of moisture negatively impacts the development of the plant organism, which directly manifests as a decrease in the generative potential of varieties. In the Kaliningrad region, more than 70% of agricultural landscapes have been converted to arable land thanks to technical solutions for water reclamation — using a closed ceramic drainage system with water discharge into an open channel. Within the drained agro-landscapes of the region, elements of local secondary waterlogging are observed, with signs of gleying [8], [9] appearing in the lower soil horizons of the morphological profile. The formation of waterlogging (rising groundwater levels, formation of surface water) creates an edaphotopic environment in agrocenoses that is detrimental to plant growth, manifesting as necrosis of their tissues, first at the tip of the leaf blade, then at the growth point, stem, and tillering node. The partial or complete death of plants under such conditions depends on the duration of flooding and negative temperatures during the winter period.

The dominant agricultural crops for winter sowing in the Kaliningrad region are rapeseed and wheat. The share of winter wheat in the 2025 sowing amounted to 82%, while barley and rye accounted for 14% and 4%, respectively. The allocation of significant areas for winter wheat is explained by the indispensable value of the product for the country's food security and high seed yield [10], [11], [13], [14]. In 2024, the Kaliningrad region ranked among the top five regions in Russia for wheat yield, taking second place with 59.3 centners per hectare; the total grain harvest of wheat amounted to 436.57 thousand tons (figure) [15], [16].

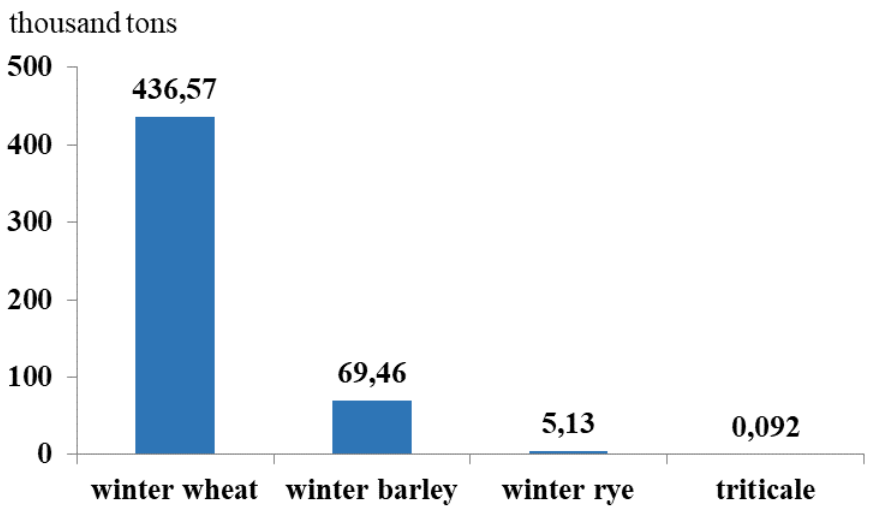


Figure 1 - Gross harvest of winter crops in 2024 in the Kaliningrad region
DOI: https://doi.org/10.60797/JAE.2025.64.12.1

Note: authors' calculations based on [17], [18]

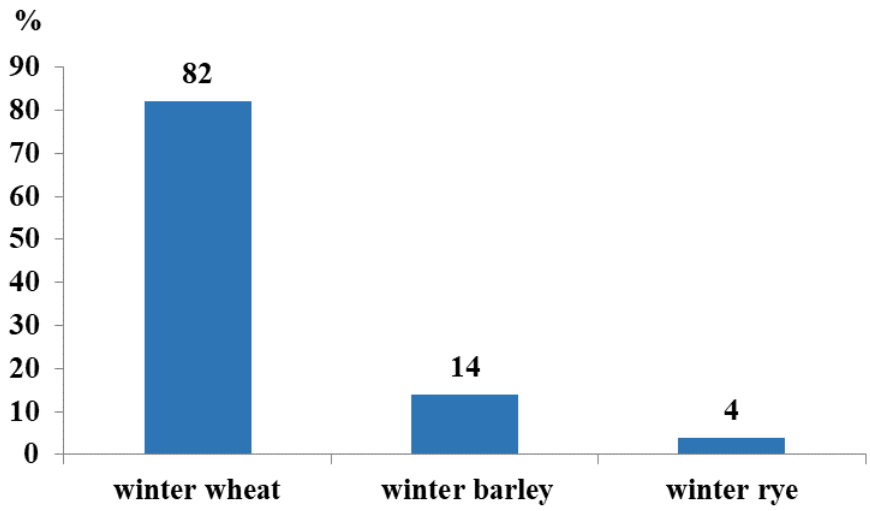


Figure 2 - Winter crops in 2025 sowings in the Kaliningrad region
DOI: https://doi.org/10.60797/JAE.2025.64.12.2

Note: authors' calculations based on [15]

The issue of monitoring agrocenoses of winter crops to assess the overwintering of plants is particularly relevant in the distinctive climatic conditions of the Kaliningrad region [6], [18], which has a humid climate (moisture coefficient — 1.3) [8].

The objective is to monitor the overwintering of winter wheat plants of the Sinava variety on drained sod-podzolic and sod-gley soils in the Kaliningrad region under conditions of possible secondary waterlogging.

Research method

Object of Study: Winter wheat (Triticum aestivum L.) of the Sinava variety (hybrid population Lutescens ABCG x Mironovskaya 67) of intensive type; variety Lutescens; reproduction II. The originator of the variety is the Federal State Budgetary Scientific Institution "Federal Scientific Center for Leguminous and Cereal Crops," LLC "ZBK-Center," and JSC "Shchelkovo-Agrohim" [19].

Sowing Dates: September 17, 2021, and September 20, 2024; sowing rate: 210 kg/ha; sowing method: narrow-row; predecessor: winter rapeseed. Spring fertilization of winter wheat with nitrogen fertilizers is carried out in March (March 13, 2022, and March 25, 2025).

The winter wheat crops were located on drained sod-podzolic and sod-gley semi-hydromorphic soils within the Polesskaya Lowland. The entity managing land resources is the Kaliningrad Research Institute of Agriculture — a branch of the Federal State Budgetary Scientific Institution "Federal Scientific Center for Forage Production and Agroecology named after V.R. Williams." This land area has been designated as a cultural forage land of pasture and haymaking type with a regulated grazing system for over 30 years, maintaining its purpose until 2018 [20], [21]. Field and agrometeorological observations and analyses were conducted from October 2021 to March 2025. The density of plant stands was determined using trial plots of 0.25 m² in four repetitions at the end of the autumn vegetation period (quantitative method) and at the beginning of the spring vegetation period (quantitative and weight method) (GOST 20915-75), expressed as an arithmetic mean:

$$A = a/S \tag{1}$$

where: a — the number of encountered individuals (stems) of plants;

S — total accounting area, m².

The condition of the crops was assessed using the following grading scale: excellent condition — at least 400 plants; good — 300–400 plants; satisfactory — 200–300 plants; poor — less than 200 plants; 130 or more plants per square meter — the area is subject to reseeding; less than 130 plants — reseeding is carried out.

Results and discussion

The agroclimatic conditions during the autumn-winter-spring period of 2021-2022 and 2024-2025 are objectively assessed as typical for the Kaliningrad region. The winter was mild, influenced by the maritime climate. Air temperatures in winter varied from 6 to -1°C (Figure 3), with high humidity levels of 75–95%. There were three instances of snowfall (the last decade of November, the first decade of January, and the second to third decades of February), with a snow cover lasting from 5 to 11 days and a rapid snowmelt. There was no soil freezing during the winter period of 2021–2022, and there was also no snow cover. In contrast, soil freezing during the winter period of 2024–2025 reached 8–10 cm. The maximum snow cover height was 12 cm (on February 19, 2025); the hydrological load after snowmelt in the experimental field was 12 l/m², which is equivalent to 12 mm.

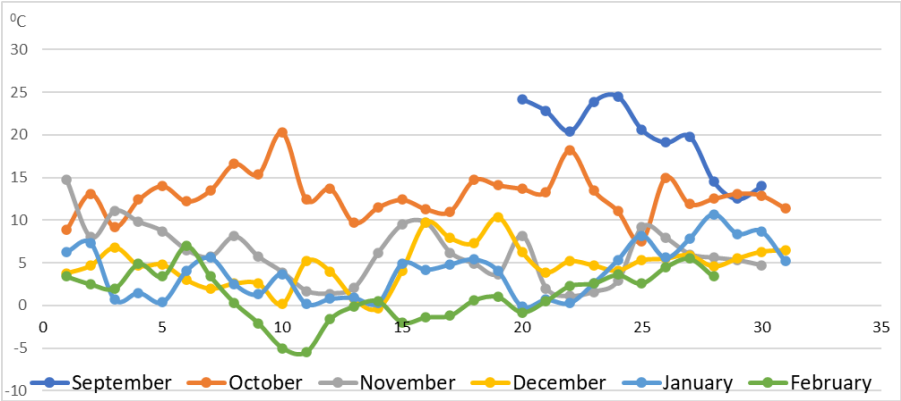


Figure 3 - Dynamics of maximum air temperatures in the autumn-winter-spring period in the Kaliningrad region on average for the years 2021-2022 and 2024-2025
DOI: https://doi.org/10.60797/JAE.2025.64.12.3

Note: authors' calculations based on [17]

Sharp short-term temperature minima were not recorded in the Kaliningrad region during the winter period of 2021-2022. However, on February 20, 2025, the air temperature dropped to minus 20°C (see Fig. 4), followed by an anomalously sharp increase to 5°C within three hours of the daily temperature cycle. During this period, winter crops were covered by a loose snow layer, which reached a height of 12 cm in the experimental field, protecting the aboveground biomass from freezing.

In the winter periods of 2021–2022 and 2024–2025, there were no prolonged heavy rainfall events, which are characteristic of the region. The highest average precipitation during the studied periods occurred in the second half of November — 37.4–38.6 mm; in the first and third decades of January — 30.5–38 mm; and in mid-February — up to 30.8 mm, coinciding with snowfall periods.

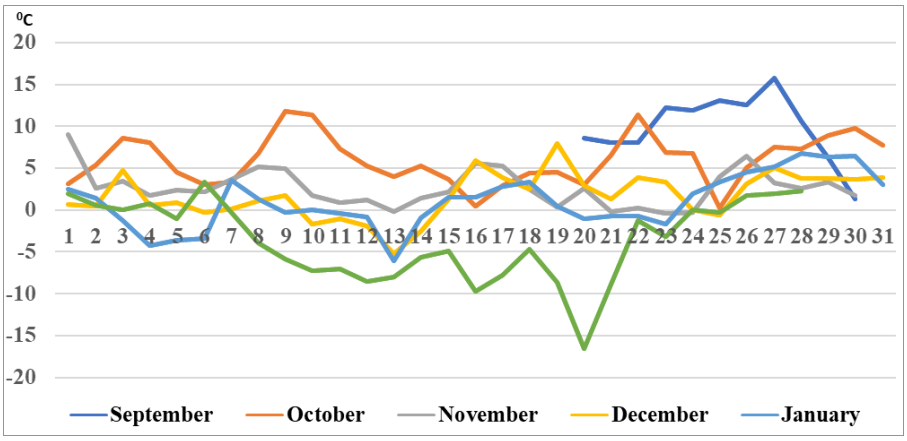


Figure 4 - Dynamics of minimum daily air temperatures in the autumn-winter-spring period in the Kaliningrad region on average for the years 2021-2022 and 2024-2025
DOI: https://doi.org/10.60797/JAE.2025.64.12.4

Note: authors' calculations based on [17]

From October to February, the Kaliningrad region receives an average of about 352.66 mm of precipitation (see Fig. 5).

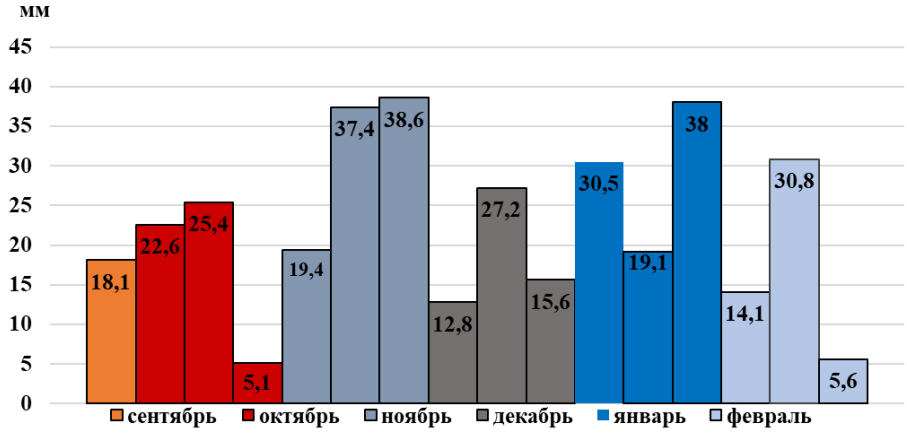


Figure 5 - Total precipitation per decade since sowing
DOI: https://doi.org/10.60797/JAE.2025.64.12.5

Note: authors' calculations based on [17]

In the conditions of a humid climate and the presence of gleic soils, with gleyness in the lower soil horizons, signs of soil overmoistening manifested locally on the surface of the studied field in the form of "water lenses" — secondary overmoistening of drained soils. The sizes of the flooded areas ranged from 60 to 260 m². Seven such areas were identified in this field. On one of them, the surface water reached 16–18 cm (in the experimental field area with turf-gley soils), while in the others, it was up to 4–8 cm (in the elementary soil area with turf-slightly podzolized gleic soils).

The conditions of overmoistening in the edaphotopic environment of the agroecosystem of winter wheat affected the state of the plants during their winter dormancy. Under overmoistening conditions, degradation processes were recorded in the main tissues of the upper parts of the leaf blades (on January 18, 2022, and January 26, 2025), which resulted in a reduction of healthy leaf area (Figure 6).

A B

Figure 6 - Condition of winter wheat crops in soaking areas in the conditions of the Kaliningrad region:
A - in conditions of waterlogged soils; *B* - in conditions of moderate moisture
DOI: https://doi.org/10.60797/JAE.2025.64.12.6

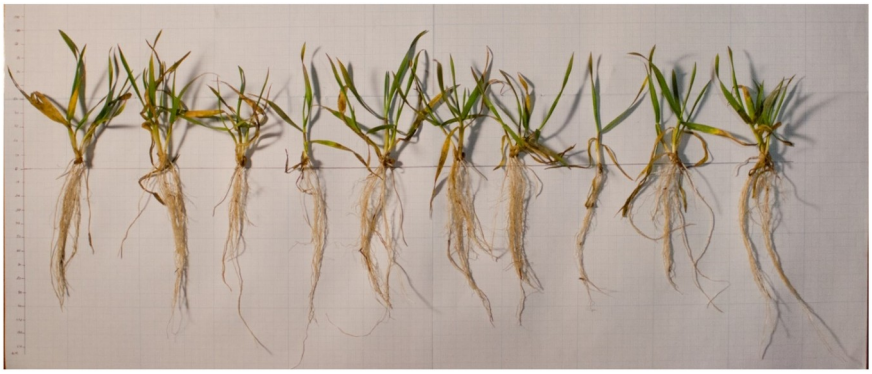
Note: for example, plants from January 26, 2025

Crops in areas of waterlogging experience oxygen root "starvation" — the leaves are wilted, yellow, and brown in places, and the leaf sheaths and roots have also changed color from the normal milk-white to straw-yellow. The formation of the root system under conditions of soil overmoistening is characterized by the elongation of some adventitious roots. The average plant density over the two studied winter periods was 384±14 plants/m².

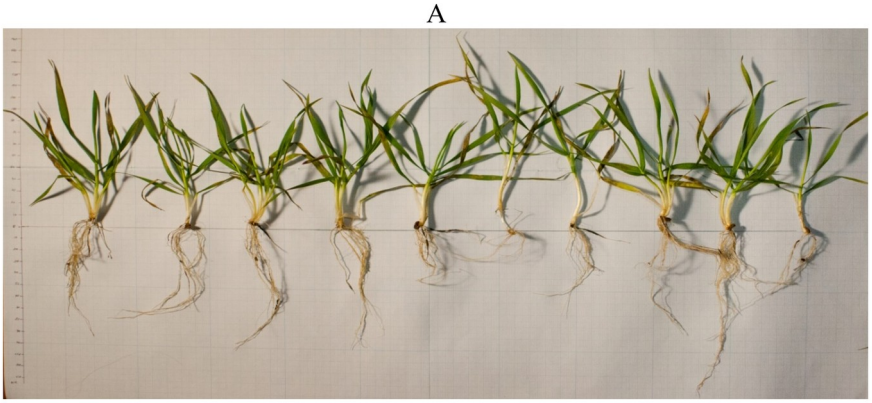
Overmoistening of the plant growth environment primarily manifests as partial necrosis of the protective, fundamental, and conducting tissues of the leaf blade. A decrease in biomass from 539.84±29.6 g/m² (under moderate overmoistening) to 343.52±13.7 g/m², and by 85–90% (under flooding conditions), which in percentage terms is 36.37%, was observed 10 days after spring fertilization.

When daytime temperatures in March rose to 8-15°C and remained at that level for 7 days, a resumption of tillering and plant growth was noted. At a soil moisture content (SMC) of 36.8%, the resumption of vegetation was more intense compared to plants growing in soil with an SMC of 41.44% (Figure 7), which exhibited low vitality, with significantly fewer healthy leaf

blades remaining by that time. When SMC increased to 55.12%, a mortality rate of 85-90% of the plant organisms was recorded. This generally corresponded to areas where surface water was present.



A



B

Figure 7 - Assessment of the condition of plants in the agrophytocenosis of winter wheat in mid-March in the conditions of the Kaliningrad region:
A - in conditions of waterlogged soils; *B* - in conditions of moderate soil moisture
DOI: https://doi.org/10.60797/JAE.2025.64.12.7

In the overall condition of the winter wheat crop by mid-March, a critical period was noted in the need for nitrogen nutrition — the beginning of the 21–23 development stage (according to BBCH), mitigated by the application of nitrate-ammonium fertilizer (NH_4NH_3) at a rate of 100 kg/ha. The assessment of plant density per square meter showed that the number of plants under prolonged soil overmoistening decreased by 7.5%, while the productivity of underground and aboveground biomass was lower by 196.32±32.1 g/m².

Conclusion

In the conditions of the Kaliningrad region, the most likely occurrence is the development of waterlogging in gley soils. In this regard, monitoring and the creation of ecological-hydrological passports for fields are necessary to make targeted, economically justified decisions for optimizing the water-air regime of soils.

Waterlogging of soils during the overwintering period of winter crops can be classified as a separate risk group, as it is forecasted to lead to a decrease in the productivity of cereal crops. This forecast will be localized, specifically for areas of the agro-phytocenosis where surface water has accumulated.

Waterlogging of the plant habitat primarily affects the partial necrosis of protective, fundamental, and conducting tissues of the leaf blade. A decrease in biomass from 539.84±29.6 g/m² (under conditions of moderate waterlogging) to 343.52±13.7 g/m², and by 85-90% (under flooding conditions), which in percentage terms amounts to 36.37%, was observed 10 days after spring fertilization.

Конфликт интересов

Не указан.

Рецензия

Все статьи проходят рецензирование. Но рецензент или автор статьи предпочли не публиковать рецензию к этой статье в открытом доступе. Рецензия может быть предоставлена компетентным органам по запросу.

Conflict of Interest

None declared.

Review

All articles are peer-reviewed. But the reviewer or the author of the article chose not to publish a review of this article in the public domain. The review can be provided to the competent authorities upon request.

Список литературы / References

1. Вилюнов С.Д. Оценка перезимовки озимой пшеницы различными вегетационными индексами / С.Д. Вилюнов, В.С. Сидоренко, М.А. Шапорова [и др.] // Зернобобовые и крупяные культуры. — 2024. — № 3 (51). — С. 100–105. — DOI: 10.24412/2309-348X-2024-3-100-105. — EDN: NNDQHF.

2. Афанасьева Ю.В. Оценка устойчивости коллекционных образцов озимой пшеницы к стрессовым факторам зимнего периода / Ю.В. Афанасьева // Аграрная наука. — 2024. — № 11. — С. 122–128. — DOI: 10.32634/0869-8155-2024-388-11-122-128.

3. Guo J. Risk assessment of freezing injury during overwintering of wheat in the northern boundary of the Winter Wheat Region in China / J. Guo, X. Bai, W. Shi [et al.] // Peer J. — 2021. — Vol. 9. — № 9. — Art. e12154. — DOI: 10.7717/peerj.12154.

4. Дорохов Б.А. Изменение климата и условия перезимовки озимой пшеницы на Юго-востоке ЦЧЗ / Б.А. Дорохов // Глобальные климатические изменения: региональные эффекты, модели, прогнозы : Материалы международной научно-практической конференции, Воронеж, 03–05 октября 2019 года / Под общ. ред. С.А. Куролапа, Л.М. Акимова, В.А. Дмитриевой. — Воронеж: Цифровая полиграфия, 2019. — Т. 2. — С. 56–58. — EDN: HTQKNK.

5. Исмагилов К.Р. Агроклиматические риски возделывания озимых зерновых культур / К.Р. Исмагилов, Л.М. Хасанова // Современное состояние, традиции и инновационные технологии в развитии АПК : Материалы международной научно-практической конференции, посвященной 90-летию Башкирского государственного аграрного университета (в рамках XXX международной специализированной выставки «Агрокомплекс-2020»), Уфа, 17–20 марта 2020 года. — Уфа: Башкирский государственный аграрный университет, 2020. — Т. 1. — С. 137–141. — EDN: FMGFNX.

6. Анциферова О.А. Продуктивность озимой пшеницы на фоне лимитирующих почвенных факторов / О.А. Анциферова, Е.Д. Самарина // Известия КГТУ. — 2018. — № 49. — С. 172–183. — EDN: RQLHDT.

7. Болохонцева Ю.И. Влияние минерального питания на урожайность озимой пшеницы в условиях курской области / Ю.И. Болохонцева, Р.И. Овчинникова // Вестник Курской государственной сельскохозяйственной академии. — 2024. — № 4. — С. 33–40.

8. Анциферова О.А. Эколого-гидрологическое состояние и продуктивность осушенных почв агроландшафта Самбийской равнины / О.А. Анциферова, Д.Н. Сафонова // Агрофизика. — 2022. — № 1. — С. 1–10. — DOI: 10.25695/AGRPH.2022.01.01. — EDN: ZPPTOE.

9. Анциферова О.А. Оценка вторично переувлажненных почв в осушенных агроландшафтах Калининградской области / О.А. Анциферова // Почвенные и земельные ресурсы: традиционные и инновационные подходы к изучению и управлению : материалы междунар. науч.-практ. конф., посвящ. 90-летию образования каф. почвоведения и геоинформ. систем БГУ и 85-летию со дня рождения д-ра геогр. наук, проф. В. С. Аношко, Минск, 21–24 сент. 2023 г. — Минск: БГУ, 2023. — С. 40–44.

10. Перунов Р.В. Влияние на появление всходов сортов озимой пшеницы погодных условий и сроков посева / Р.В. Перунов, Н.М. Гончарова // Вестник Курской государственной сельскохозяйственной академии. — 2025. — № 1. — С. 30–34.

11. Силяева Е.С. Народнохозяйственное значение озимой пшеницы и ее роль в продовольственной безопасности страны / Е.С. Силяева // Научный журнал молодых ученых. — 2019. — № 4 (17). — С. 39–43. — EDN: QWRMJE.

12. Abys Ch. Two decades of winter wheat expansion and intensification in Russia / Ch. Abys, S. Skakun, I. Becker-Reshef // Remote Sensing Applications: Society and Environment. — 2024. — № 33. — Art. 101097. — DOI: 10.1016/j.rsase.2023.101097.

13. González-García S. Evaluating the environmental profiles of winter wheat rotation systems under different management strategies / S. González-García, M.T. Moreira, M. Brandão [et al.] // Science of the Total Environment. — 2021. — № 770. — Art. 145270. — DOI: 10.1016/j.scitotenv.2021.145270.

14. Kosová K. How to survive mild winters: Cold acclimation, deacclimation, and reacclimation in winter wheat and barley / K. Kosová, T. Nešporová, P. Vítámvás [et al.] // Plant Physiology and Biochemistry. — 2025. — № 220. — Art. 109541. — DOI: 10.1016/j.plaphy.2025.109541.

15. Калининградская область стала второй в России по урожайности зерновых и зернобобовых культур // Министерство сельского хозяйства Калининградской области. — URL: https://mcx.gov39.ru/press-center/novosti/338566/ (дата обращения: 25.03.2025).

16. Маркевич М. Калининградская область лидирует по урожайности зерновых и зернобобовых / М. Маркевич // РБК. — URL: https://kaliningrad.rbc.ru/kaliningrad/23/08/2023/64e5e4799a794791be45927c (дата обращения: 25.03.2025).

17. Архив погоды в Калининграде (Калининградская область, Россия) // Погода и климат. — URL: http://www.pogodaiklimat.ru/weather.php?id=26702 (дата обращения: 25.03.2025).

18. Вилюнов С.Д. Оценка перезимовки озимой пшеницы различными вегетационными индексами / С.Д. Вилюнов, В.С. Сидоренко, М.А. Шапорова [и др.] // Зернобобовые и крупяные культуры. — 2024. — № 3 (51). — С. 100–105. — DOI: 10.24412/2309-348X-2024-3-100-105. — EDN: NNDQHF.

19. Хмелева Е.В. Технологический потенциал новых сортов пшеницы Орловской селекции / Е.В. Хмелева, Р.Х. Кандроков, Н.А. Березина [и др.] // Зернобобовые и крупяные культуры. — 2023. — № 4 (48). — С. 110–122. — DOI: 10.24412/2309-348X-2023-4-110-122. — EDN: HDVROL.

20. Красноперов А.Г. Прифермские кормовые угодья, состояние, перспективы / А.Г. Красноперов, Н.И. Буянкин, Т.Н. Троян [и др.] // Адаптивное кормопроизводство. — 2019. — № 4. — С. 27–35. — DOI: 10.33814/AFP-2222-5366-2019-4-27-35. — EDN: RJRVSX.

21. Троян Т.Н. Влияние долголетнего сенокосно-пастбищного использования на динамику гумуса и кислотность почв / Т.Н. Троян, А.А. Кондрацкая // Известия КГТУ. — 2018. — № 50. — С. 138–150.

Список литературы на английском языке / References in English

1. Vilyunov S.D. Otsenka perezimovki ozimoi pshenitsi razlichnimi vegetatsionnimi indeksami [Assessment of winter wheat overwintering using various vegetation indices] / S.D. Vilyunov, V.S. Sidorenko, M.A. Shaporova [et al.] // Zernobobovie i krupyanie kulturi [Grain Legumes and Cereals]. — 2024. — № 3 (51). — P. 100–105. — DOI: 10.24412/2309-348X-2024-3-100-105. — EDN: NNDQHF. [in Russian]

2. Afanaseva Yu.V. Otsenka ustoichivosti kollektsionnikh obraztsov ozimoi pshenitsi k stressovim faktoram zimnego perioda [Evaluation of resistance of collection samples of winter wheat to stress factors of the winter period] / Yu.V. Afanaseva // Agrarnaya nauka [Agrarian Science]. — 2024. — № 11. — P. 122–128. — DOI: 10.32634/0869-8155-2024-388-11-122-128. [in Russian]

3. Guo J. Risk assessment of freezing injury during overwintering of wheat in the northern boundary of the Winter Wheat Region in China / J. Guo, X. Bai, W. Shi [et al.] // Peer J. — 2021. — Vol. 9. — № 9. — Art. e12154. — DOI: 10.7717/peerj.12154.

4. Dorokhov B.A. Izmenenie klimata i usloviya perezimovki ozimoi pshenitsi na Yugo-vostoke TsChZ [Climate change and winter wheat overwintering conditions in the south-east of the Central Black Earth Region] / B.A. Dorokhov // Globalnie klimaticheskie izmeneniya: regionalnie effekti, modeli, prognozi : Materiali mezhdunarodnoi nauchno-prakticheskoi konferentsii, Voronezh, 03–05 oktyabrya 2019 goda [Global climate change: regional effects, models, forecasts: Proceedings of the International Scientific and Practical Conference, Voronezh, 3–5 October 2019] / Under gen. ed. of S.A. Kurolap, L.M. Akimov, V.A. Dmitrievoa. — Voronezh: Digital Printing, 2019. — Vol. 2. — P. 56–58. — EDN: HTQKNK. [in Russian]

5. Ismagilov K.R. Agroklimaticheskie riski vozdelivaniya ozimikh zernovikh kultur [Agroclimatic risks of winter grain cultivation] / K.R. Ismagilov, L.M. Khasanova // Sovremennoe sostoyanie, traditsii i innovatsionnie tekhnologii v razvitii APK : Materiali mezhdunarodnoi nauchno-prakticheskoi konferentsii, posvyashchennoi 90-letiyu Bashkirskogo gosudarstvennogo agrarnogo universiteta (v ramkakh XXX mezhdunarodnoi spetsializirovannoi vistavki «Agrokompleks-2020»), Ufa, 17–20 marta 2020 goda [Current state, traditions and innovative technologies in the development of the agro-industrial complex: Proceedings of the International Scientific and Practical Conference dedicated to the 90th anniversary of Bashkir State Agrarian University (as part of the XXX International Specialised Exhibition ‘Agrocomplex-2020’), Ufa, 17–20 March 2020]. — Ufa: Bashkir State Agrarian University, 2020. — Vol. 1. — P. 137–141. — EDN: FMGFNX. [in Russian]

6. Antsiferova O.A. Produktivnost ozimoi pshenitsi na fone limitiruyushchikh pochvennikh faktorov [Winter wheat productivity in the context of limiting soil factors] / O.A. Antsiferova, Ye.D. Samarina // Izvestiya KGTU [News of KSTU]. — 2018. — № 49. — P. 172–183. — EDN: RQLHDT. [in Russian]

7. Bolokhontseva Yu.I. Vliyanie mineralnogo pitaniya na urozhainost ozimoi pshenitsi v usloviyakh kurskoi oblasti [The influence of mineral nutrition on winter wheat yield in Kursk Oblast] / Yu.I. Bolokhontseva, R.I. Ovchinnikova // Vestnik Kurskoi gosudarstvennoi selskokhozyaistvennoi akademii [Bulletin of the Kursk State Agricultural Academy]. — 2024. — № 4. — P. 33–40. [in Russian]

8. Antsiferova O.A. Ekologo-gidrologicheskoe sostoyanie i produktivnost osushennikh pochv agrolandshafta Sambiiskoi ravnini [Ecological and hydrological condition and productivity of drained soils in the agricultural landscape of the Sambian Plain] / O.A. Antsiferova, D.N. Safonova // Agrofizika [Agrophysics]. — 2022. — № 1. — P. 1–10. — DOI: 10.25695/AGRPH.2022.01.01. — EDN: ZPPTOE. [in Russian]

9. Antsiferova O.A. Otsenka vtorichno pereuvlazhnennikh pochv v osushennikh agrolandshaftakh Kaliningradskoi oblasti [Assessment of re-waterlogged soils in drained agricultural landscapes of Kaliningrad Oblast] / O.A. Antsiferova // Pochvennie i zemelnie resursi: traditsionnie i innovatsionnie podkhodi k izucheniyu i upravleniyu : materiali mezhdunar. nauch.-prakt. konf., posvyashch. 90-letiyu obrazovaniya kaf. pochvovedeniya i geoinform. sistem BGU i 85-letiyu so dnya rozhdeniya d-ra geogr. nauk, prof. V. S. Anoshko, Minsk, 21–24 sent. 2023 g. [Soil and land resources: traditional and innovative approaches to study and management: materials from the International Scientific and Practical Conference dedicated to the 90th anniversary of the Department of Soil Science and Geoinformation Systems at Belarusian State University and the 85th anniversary of the birth of Dr. V.S. Anoshko, Professor of Geography, Minsk, 21–24 September 2023] — Minsk: BSU, 2023. — P. 40–44. [in Russian]

10. Perunov R.V. Vliyanie na poyavlenie vskhodov sortov ozimoi pshenitsi pogodnikh uslovii i srokov poseva [The influence of weather conditions and sowing dates on the emergence of winter wheat varieties] / R.V. Perunov, N.M. Goncharova // Vestnik Kurskoi gosudarstvennoi selskokhozyaistvennoi akademii [Bulletin of the Kursk State Agricultural Academy]. — 2025. — № 1. — P. 30–34. [in Russian]

11. Silyaeva Ye.S. Narodnokhozyaistvennoe znachenie ozimoi pshenitsi i yee rol v prodovolstvennoi bezopasnosti strani [The economic importance of winter wheat and its role in the country's food security] / Ye.S. Silyaeva // Nauchnii zhurnal molodikh uchenikh [Scientific Journal of Young Scientists]. — 2019. — № 4 (17). — P. 39–43. — EDN: QWRMJE. [in Russian]

12. Abys Ch. Two decades of winter wheat expansion and intensification in Russia / Ch. Abys, S. Skakun, I. Becker-Reshef // Remote Sensing Applications: Society and Environment. — 2024. — № 33. — Art. 101097. — DOI: 10.1016/j.rsase.2023.101097.

13. González-García S. Evaluating the environmental profiles of winter wheat rotation systems under different management strategies / S. González-García, M.T. Moreira, M. Brandão [et al.] // Science of the Total Environment. — 2021. — № 770. — Art. 145270. — DOI: 10.1016/j.scitotenv.2021.145270.

14. Kosová K. How to survive mild winters: Cold acclimation, deacclimation, and reacclimation in winter wheat and barley / K. Kosová, T. Nešporová, P. Vítámvás [et al.] // Plant Physiology and Biochemistry. — 2025. — № 220. — Art. 109541. — DOI: 10.1016/j.plaphy.2025.109541.

15. Kaliningradskaya oblast stala vtoroi v Rossii po urozhainosti zernovikh i zernobobovikh kultur [Kaliningrad Oblast ranks second in Russia in terms of grain and legume crop yields] // Ministry of Agriculture of Kaliningrad Oblast. — URL: https://mcx.gov39.ru/press-center/novosti/338566/ (accessed: 25.03.2025). [in Russian]

16. Markevich M. Kaliningradskaya oblast lidiruet po urozhainosti zernovikh i zernobobovikh [Kaliningrad Oblast leads in grain and legume yields] / M. Markevich // RBC. — URL: https://kaliningrad.rbc.ru/kaliningrad/23/08/2023/64e5e4799a794791be45927c (accessed: 25.03.2025). [in Russian]

17. Arkhiv pogodi v Kaliningrade (Kaliningradskaya oblast, Rossiya) [Weather archive for Kaliningrad (Kaliningrad Oblast, Russia)] // Pogoda i klimat [Weather and climate]. — URL: http://www.pogodaiklimat.ru/weather.php?id=26702 (accessed: 25.03.2025). [in Russian]

18. Vilyunov S.D. Otsenka perezimovki ozimoi pshenitsi razlichnimi vegetatsionnimi indeksami [Evaluation of winter wheat overwintering using various vegetation indices] / S.D. Vilyunov, V.S. Sidorenko, M.A. Shaporova [et al.] // Zernobobovie i krupyanie kulturi [Grain Legumes and Cereals]. — 2024. — № 3 (51). — P. 100–105. — DOI: 10.24412/2309-348X-2024-3-100-105. — EDN: NNDQHF. [in Russian]

19. Khmeleva Ye.V. Tekhnologicheskii potentsial novikh sortov pshenitsi Orlovskoi selektsii [Technological potential of new wheat varieties bred in Oryol] / Ye.V. Khmeleva, R.Kh. Kandrokov, N.A. Berezina [et al.] // Zernobobovie i krupyanie kulturi [Grain Legumes and Cereals]. — 2023. — № 4 (48). — P. 110–122. — DOI: 10.24412/2309-348X-2023-4-110-122. — EDN: HDVROL. [in Russian]

20. Krasnoperov A.G. Prifermskie kormovie ugodya, sostoyanie, perspektivi [Farmland forage crops, current status and prospects] / A.G. Krasnoperov, N.I. Buyankin, T.N. Troyan [et al.] // Adaptivnoe kormoproizvodstvo [Adaptive forage production]. — 2019. — № 4. — P. 27–35. — DOI: 10.33814/AFP-2222-5366-2019-4-27-35. — EDN: RJRVSX. [in Russian]

21. Troyan T.N. Vliyanie dolgoletnego senokosno-pastbishchnogo ispolzovaniya na dinamiku gumusa i kislotnost pochv [The impact of long-term haymaking and grazing on humus dynamics and soil acidity] / T.N. Troyan, A.A. Kondratskaya // Izvestiya KGTU [News of KSTU]. — 2018. — № 50. — P. 138–150. [in Russian]