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SOIL MOISTURE RESERVES AND DEVELOPMENT OF WINTER WHEAT PLANTS DURING THE AUTUMN VEGETATION IN THE NORTHERN STEPPE OF UKRAINE

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Topicality. *Knowledge of the trends and patterns of influence of atmospheric phenomena, in particular air temperature and precipitation, on the formation of certain yield attributes of winter wheat, allows us to avoid or significantly mitigate the negative effect of a certain weather factor that in some cases plays a decisive role in ensuring the emergence of friendly sprouts, plant development in autumn and plant condition before overwintering.* ***Purpose.*** *To determine the influence of weather conditions in autumn on the soil moisture availability and the condition of winter wheat plants grown after sunflower before overwintering in the Northern Steppe of Ukraine.* ***Materials and Methods.*** *The study and analysis of problematic issues was carried out at the Synelnykove Breeding and Research Station in the crop rotation of the Laboratory of Agrobiological Resources of Winter Grain Crops of SE Institute of Grain Crops of NAAS during 2019–2024. The winter wheat cultivation technology is generally accepted for the Northern Steppe of Ukraine. Sampling of soil and plants was carried out in accordance with existing recommendations.* ***Results****. Weather conditions during the autumn vegetation largely determined the condition of winter wheat crops at the beginning of the winter period. In 2019–2024, the average air temperature and precipitation in September-November were 10.8 °C and 114.6 mm, respectively, which was 1.6 °C higher and 2.4 mm lower than the long-term average. High temperatures and a prolonged lack of precipitation almost every year resulted in a critical decrease in productive soil moisture reserves at the time of sowing winter wheat, which averaged only 2 mm in the 0–10 cm soil layer, 4 mm in the 0–20 cm layer, 10 mm in the 0–50 cm layer, and 17 mm in the 0–100 cm layer, which was 21–25 % of the long-term average. The amount of precipitation did not meet the moisture needs of the plants during the autumn vegetation, and thus the average amount of available moisture in the arable and one-metre layers of soil at the autumn vegetation cessation was only 16 mm and 45 mm, respectively, or 50 and 44 % of the average long-term norm. As a result, the biometric parameters of winter wheat plants before overwintering in most years did not correspond to optimal values, which primarily ensured high frost tolerance of winter wheat plants, as a result - plants were 13-15 cm high, with an average of 1.1–1.4 shoots and 1.8–2.7 nodal roots.* ***Conclusions.*** *It was found that soil moisture availability during the autumn period in most years did not meet the moisture needs of winter wheat plants, as a result, the plants began wintering in a relatively weak morphophysiological condition. Nevertheless, the elevated air temperature during the calendar winter allowed winter crops of optimal sowing dates to successfully complete the winter period, with virtually no losses.*

Key words: *winter wheat, weather conditions, soil moisture reserves, autumn vegetation, plant condition*

Introduction. In recent years, global warming has been a key factor in shaping Ukraine's climate in the steppe zone, so weather conditions during the growing season of winter crops have been quite favourable for plant growth and productivity. First and foremost, warming affects the hydrothermal regime, which is the basis of a complex system of relationships between plant organisms, the environment and elements of technology for growing a particular crop. At the same time, although the Steppe of Ukraine, in particular its northern part, is cha-racterised by relatively good heat and moisture ratios for growing winter wheat (*Triticum aestivum* L.), the level of its viability is determined mainly by the conditions of water supply during the growing season, which is based on precipitation.

It is proved that the influence of weather

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conditions on the formation of the productivity of the main grain crop is 20–40% depending on the cultivation technologies, and in years with extreme meteorological phenomena this influence increases to 60–70% and more [1–3].

Gradual climate changes over the past decades have led to noticeable, sometimes sharp fluctuations in weather parameters and increasingly frequent droughts during the growing season. Nonetheless, a rise in air temperature up to a certain limit is generally favourable for growing not only winter wheat but also other winter crops. The most important is the significant warming of the late autumn and winter periods, which allows plants to accumulate sufficient vegetative biomass to successfully overwinter, creating good conditions for their further spring and summer vegetation and the formation of the main yield attributes [4–6].

As is known, the most favourable temperature for seed germination of winter wheat is 12–18 °C, which ensures the emergence of even seedlings within 6–9 days. Higher air temperatures (above 25 °C) are unfavourable for seed germination, as they can cause severe disease infection of seedlings, and at temperatures of 40 °C with a relative humidity of 30 % and below, germinated seeds die due to intense moisture evaporation, and those that have swollen lose germination due to respiration, nutrient consumption and pathogen damage [7–10].

The aridity of the climate in the Steppe zone is caused not only by insufficient precipitation, but also by its uneven distribution over the months, increased water consumption for transpiration and evaporation from the soil surface, which is more manifested in summer and early autumn [11–13]. Therefore, in both dry and moderately wet years, the harvest is directly dependent on the level of water consumption by wheat. Usually, plants consume moisture most efficiently after those predecessors that leave more moisture content in the soil, especially in topsoil. The water consumption of the main grain crop and its moisture availability are determined by many factors, in particular, the volume of vegetative mass of plants and plant population per unit area, which largely depends on technological factors (varietal characteristics, predecessors, fertilisers, sowing dates, seeding rates, etc.), as well as productive moisture reserves in the soil at the sowing date, which determine the friendly emergence of seedlings, intensive development of plants in autumn and their successful overwintering [14–16].

In crop production, the importance of moisture is well known. Plants generally contain around 90 % water by fresh weight. Seed germination is greatly dependent on post-sowing conditions, among which moisture availability and soil temperature are crucial factors. As you know, winter wheat is quite demanding on moisture content, as seeds germinate and absorb about 50–55 % of water by their own weight. Therefore, the moisture deficit in the soil at the time of sowing wheat in the early autumn often results in significant damage to crops (sometimes with catastrophic consequences), as friendly and timely seedlings emergence of this crop occurs only when the soil layer of 0–10 cm contains 10 mm or more of available moisture. In general, insufficient water availability for winter wheat is the main factor that prevents it from realising its full productivity potential. Moreover, the law of the minimum determines the ecological limit of the yield in specific conditions [17–20].

The productive moisture reserves in the soil are the main factor in the soil-plant connection, which is crucial for producing friendly seedlings and further vegetation of agricultural crops. Insufficient moisture content in the soil not only negatively affects plant development, but also significantly reduces the effectiveness of certain elements of cultivation technology. Therefore, the issues of dynamics and rational use of soil moisture reserves and precipitation by winter wheat agrocenoses remain scientifically relevant and significant in practice. Given the impact of weather conditions on the formation of individual elements of productivity for this crop, this knowledge and operational information should be used to partially compensate for possible adverse effects of abiotic factors on the quantitative value of the harvest [21–24].

The initial period of winter wheat development is crucial in the formation of highly productive crops, as this period largely ensures further growth and development of plants and the final result. According to long-term observations and practice, timely and full-fledged seedlings contribute to the fact that crops develop well in autumn, plants quickly accumulate aboveground mass and have a powerful root system, and usually produce high grain yields, even under adverse weather conditions during the spring and summer growing season. On the contrary, crops that are poorly developed and thinned out in autumn produce almost always low yields [25, 26].

According to the majority of scientists, the autumn soil drought before sowing and during the autumn growing season is the most dangerous for winter crops, especially in the steppe zone, which is characterised by high temperatures and a prolonged lack of precipitation. The discrepancy between the water demand of plants and the soil water availability, which is determined by atmospheric precipitation, is the primary criterion associated with drought. Winter crops are particularly affected by the negative impact of drought, as their yields vary by 50–60 % depending on meteorological factors in different yearsActually, this is confirmed by a strong correlation between the soil moisture reserves in the 1-metre layer during sowing and wheat yield (r = 0.69–0.79) [27–30].

Given global climate change, increasingly dry weather conditions and a significant dependence of winter wheat productivity on soil moisture availability during the autumn growing season, the study was aimed at analysing the hydrothermal regime and investigating its impact on productive soil moisture reserves during the autumn growing season, as well as the state of plants at early winter in the Northern Steppe of Ukraine.

Materials and Methods. The studies and observations were carried out at the Synelnykove Breeding and Research Station in the crop rotation of the Laboratory of Agrobiological Resources of Winter Grain Crops of the Institute of Grain Crops of NAAS in accordance with existing methodologies during 2019–2024 [31, 32]. The soil of the experimental plot is ordinary chernozem. This soil had an average humus content of 3.9 % in the topsoil and a pH in the salt extract of 6.6. After seven days of composting, the nitrogen content of nitrates was 2.39–3.11 mg, and the mobile forms of phosphorus and potassium (according to Chirikov) were 11.9–17.3 and 11.3–14.7 mg per 100 g of absolutely dry soil, respectively. The area of an elementary registration plot is 50 m^2, with a repeat rate of 3 times.

In the experiment, soil and plant samples were collected on winter wheat crops sown after sunflower, which is the most common predecessor for winter cereals in the research area over the past two decades. The cultivation technology is generally accepted for the Northern Steppe of Ukraine. Sowing of winter wheat was carried out with a mounted seed drill SN-16. The sowing method was solid line sowing, with a seeding depth of 5–6 cm. The sowing date was optimal (20–25 September). Seeding rate was 5.0 million germinated seeds per hectare.

The analysis of weather conditions during the research showed that they were quite diverse both in terms of temperature and precipitation, and had a significant impact on the moisture availability of plants and the formation of their productivity. As a result, we obtained reliable information on the productive moisture reserves in the soil and the dynamics of its consumption during the autumn growing season for winter wheat cultivation after sunflower under insufficient and unstable moisture conditions in the Northern Steppe zone. In terms of atmospheric moisture, the most favourable for winter crops were the autumn periods of 2022–2023, while 2020–2021 were drier. Other years were characterised by moderate moisture, with precipitation amounts approaching the long-term average, but slightly lower than it.

Results and Discussion. Many years of practice have shown that the main agrometeorological indicators that determine the development of winter crops in autumn are air temperature, precipitation, and, as a result, soil moisture content. According to the research results, hydrothermal conditions in recent years at sowing and early autumn vegetation of winter wheat sown after sunflower were very severe and did not ensure the emergence of friendly and timely seedlings. Thus, in September, the air temperature averaged 17.2 °C over 6 years, which was 1.2 °C higher than the long-term average (Table 1). This contributed to the significant evaporation of agronomically valuable moisture from the soil, and this was also complicated by insufficient precipitation at this time – 25.1 mm, or 64.4 % of the climatological norm.

October was characterised by rather warm weather: the average air temperature was 11.2 °C, which was 2.1 °C higher than the long-term average. Such a thermal regime with a relatively sufficient amount of precipitation (an

Table 1. Agrometeorological indicators in the autumn period, 2019–2024 (according to data of the Synelnykove meteorological station)

Month	Air temperature, °C			Precipitation, mm		
	average	standard	deviation from standard	average	standard	deviation from standard
September	17.2	16.0	+1.2	25.1	39	-13.9
October	11.2	9.1	+2.1	37.6	38	-0.4
November	4.1	2.5	+1.6	51.9	40	+11.9
Average for the period	10.8	9.2	+1.6	114.6	117	-2.4
Average for the year	10.6	9.3	+1.3	521	515	+6.0

average of 37.6 mm against the norm of 38 mm) in most of the years under study allowed winter wheat to form seedlings, mainly in the middle of October, despite the sowing date in September.

Under such conditions, the seeds, which were kept in dry soil for about 30-40 days, kept field germination at a sufficiently high level, and so did not have a negative impact on winter hardiness and plant productivity and yield formation in general.

In November, an elevated temperature regime also prevailed, allowing plants to continue growth processes under sufficient atmospheric moisture supply, at least in the first half of this month, to maintain photosynthetic activity and accumulate plastic substances. In addition, such weather conditions also contributed to the cold hardening of winter crops, and as a result, their successful overwintering, efficient utilisation of mineral nutrients and drought resistance during the next spring and summer growing season. Thus, the average monthly air temperature was 4.1 °C, which was 1.6 °C above the long-term average, and precipitation was 51.9 mm, or 11.9 mm higher than usual for this calendar period. In accordance with the temperature indicators, the plants ceased active growth in early November, but during daylight hours they continued to grow until the end of the month and for some time in December, which allowed winter wheat to pass a certain stage in its development, which was primarily due to the intensity and duration of the thermal regime of the phytocenosis.

In general, the autumn period of 2019-2024 was characterised by high air temperatures and moderate precipitation, which did not ensure timely emergence of winter wheat seedlings at early and optimal sowing dates, but allowed it to start overwintering, although not in optimal, but in relatively good condition, i.e. plants usually had 2 to 4 leaves at this time and later, in case of warm winter, often started spring vegetation at the beginning of the tillering stage or with 2 shoots. During September – November period, the average air temperature was 10.8 °C, which was 1.6 °C higher than the long-term average. The average precipitation for this period was only 2.4 mm below the standard value, which had a significant impact on soil moisture availability, especially in cases where the winter wheat was preceded by sunflower, which leaves a minimum of nutrients in the soil and is capable of drying the soil to a considerable depth due to the large water consumption. Thus, grain producers face a number of problems, the solution of which depends not only on the economic potential of a particular farm, but also on the professional ability of specialists to accumulate and preserve the sufficient moisture for further growing winter crops under this predecessor by ensuring better soil absorption capacity and reducing moisture losses from physical evaporation in the post-harvest period.

Long-term data show that winter wheat plants tillering and rooting well in autumn and have a good state of development for overwintering, if the reserves of available moisture in the soil layer 0–20 cm at sowing date are 20–30 mm, and in 0–100 cm – 100–115 mm or more. However, practical activities, systematic observations and scientific research indicate that over the past three decades in the Steppe of Ukraine, soil moisture reserves before sowing winter wheat have significantly decreased. This is explained not only by poor predecessors, the lack of organic fertilisers on the fields and the deterioration of the soil structure, which accumulates and preserves atmospheric moisture, but also by weather conditions such as hydrothermal regime, which became more severe in the pre-sowing period (late summer and early autumn) [33, 34].

During the research, the increased temperature regime, prolonged lack of precipitation and dry winds of different intensity resulted in a critical decrease of productive moisture reserves in the soil almost every year at sowing of winter wheat after sunflower. And this was true not only for the topsoil, but also for the entire one-metre horizon. Thus, on a 6-year average, agronomically valuable moisture in the 0–10 cm soil layer at the optimal sowing date (20–25 September) was only 2 mm, 0–20 cm – 4 mm, 0–50 cm – 10 mm, 0–100 cm – 17 mm, which was 21–25 % of the long-term average (Table 2).

In the fields after sunflower before sowing winter wheat, the least moisture content available for plants, both in the sowing (0 mm) and in the one-metre (1–13 mm) soil layers, was observed in 2020, 2021 and 2024. The relatively better soil moisture availability, but not optimal, was in 2019, 2022 and 2023, when moisture reserves did not exceed 19–37 mm even in the one-metre horizon, which was 2–4 times less than the standards.

Table 2. Productive moisture reserves in the soil at the optimal sowing dates for winter wheat, mm (sunflower as a predecessor)

Year	Soil layers, cm			
	0–10	0–20	0–50	0–100
2024	0	0	0	2
2023	3	7	12	19
2022	8	14	24	28
2021	0	0	9	13
2020	0	0	0	1
2019	1	3	13	37
Average for 2019–2024	2	4	10	17
Long-term average	9	18	40	80

The growing conditions of winter wheat in autumn varied considerably and depended on many factors, among which the weather factor was dominant, determining the effectiveness of almost all technological elements and ensuring the degree of plant development before overwintering, the frost and winter hardiness, and the resistance to adverse weather conditions in the future. Atmospheric precipitation together with the thermal resource determined the intensity of plant growth processes and provided appropriate reserves of productive moisture in the soil, which remained rather low at the cessation of the autumn vegetation of winter wheat during 6 years of research, indicating a significant dependence of winter wheat on further precipitation in winter and early spring. Thus, in topsoil and one-metre layers of soil, the agronomic valuable moisture content before overwintering averaged only 16 mm and 45 mm, respectively, which was 50 and 44 % of the long-term average (Table 3).

Such relatively low moisture reserves in the soil from sowing to the beginning of the winter did not ensure normal growth and development of winter wheat, which was grown after sunflower. However, there was an opinion that a good condition of winter crops (tillering stage) is achieved if 20 % of the annual precipitation falls in autumn [22]. But first and foremost, this relates to winter wheat grown after the best predecessors that contributed to the accumulation and preservation of moisture in the soil, such as black and bastard fallow, after which the vast majority of the main grain crop was sown until recently. However, this thesis has not been confirmed in recent years, as significant changes in

Table 3. Productive moisture reserves in the soil at the cessation of the autumn vegetation of winter wheat, mm (sunflower as a predecessor)

Soil layers, cm	Years							Long-term average
	2019	2020	2021	2022	2023	2024	average	
0–20	15	4	11	29	38	13	16	32
0–100	36	12	33	67	103	23	45	103

winter crops predecessors have occurred – the share of non-fallow predecessors, which are harvested relatively late and remain low moisture content in the soil, has increased significantly, as well as weather conditions have become drier in the warm season and wetter in the cold seasonDespite the fact that the total annual precipitation in the Steppe of Ukhaine as slightly increased, its efficiency has slightly decreased for various reasons, primarily due to rising air temperatures and intensity of evaporation processes. Thus, the share of autumn precipitation averaged 22.7 % of the annual amount over the years of research, but there was a weak condition of winter wheat crops before overwintering, which is explained by the uneven distribution of precipitation in autumn. The main part of precipitation fell in the late autumn growing season and did not sufficiently affect the intensity of plant growth processes, as they were limited not so by moisture as by low air temperature and, as a result, by the insufficient effectiveness of mineral fertilisers applied.

In this regard, winter wheat grown after sunflower in 2019–2024 terminated the autumn growing season with an average plant density of 468 plants/m^2 and field seed germination of 94 % (Table 4).

At the same time, plants with a height of 13–15 cm had an average of 1.1–1.4 shoots and 1.8–2.7 nodal roots. During the research, winter wheat was in various physiological states before overwintering – from the full seedling stage (2021) to the tillering stage (2022), but in most years it did not meet the optimal biometric parameters that would primarily ensure its high resistance to low temperatures.

Despite the relatively weak state of the crops at the cessation of the autumn growing season, we have achieved fairly high yields of winter wheat, even for such a predecessor as sunflower, both in experiments and in production in recent years, thanks primarily to favourable winter conditions. As a result of the elevated temperatures (often up to +5 °C and above), the absence of significant soil freezing and systematic precipitation, mainly in the form of rain, the plants were able to continue their life processes. Moreover, the state of the crops improved significantly due to minimal water losses in the fields, as almost all precipitation moisture was absorbed into the soil, which allowed accumulating significant reserves for the active spring growth of winter wheat, thereby ensuring the most favourable conditions for plants in spring.

Table 4. The state of winter wheat crops at the cessation of the autumn vegetation (sunflower as a predecessor)

Indicators	Years						Average
	2019	2020	2021	2022	2023	2024	
Plant density, plants/m^2	467	474	452	470	478	467	468
Field germination, %	93	95	90	94	96	93	94
Plant height, cm	12–14	14–16	6–8	16–18	12–14	8–10	13–15
Number of shoots, pcs/plant	1.5–2.0	1.5–2.0	–	2.0–3.0	1.2–1.5	–	1.1–1.4
Number of nodal roots, pcs/plant	3–4	3–4	–	3–5	2–3	–	1.8–2.7
Plant development stage	tillering	tillering	full seedlings	tillering	the beginning of tillering	2–3 leaves	the beginning of tillering

Conclusions. Thus, soil moisture reserves during the autumn vegetation of winter wheat grown after non-fallow predecessors, in particular after sunflower, in the Northern Steppe zone of Ukraine determine the time and uniformity of seedlings emergence, plant development before overwintering and determine effectiveness of technological elements to some extent. According to the practice of recent years, in the context of climate warming, the quantitative indicators of productive moisture reserves in the soil during autumn may differ significantly from the optimal ones and do not provide the necessary state of plants before overwintering, which is usually compensated by the increased air temperature during winter, which allows winter crops not only to pass a minor stage in their development, but also to improve the moisture availability of the soil, which has a positive effect on the formation of its productivity.

References

1. Adamenko, T. (2006). Changes in agroclimatic conditions and their impact on grain farming. *Ahronom* [Agronomist], *3*. 12–15 [in Ukrainian].
2. Shevchenko, M. S., Desiatnyk, L. M., Bokun, O. I. (2020). Dynamics of productive moisture reserves in the soil and yield of spring barley depending on soil cultivation and fertilizers. *Zernovi kultury* [Cereal crops], *4 (1)*. 160–166. https://doi.org/10.31867/2 162 523-4544/0120 [in Ukrainian].
3. Adamenko, T. I. (2007). Klimatychni umovy Ukrainy ta mozhlyvi naslidky poteplinnia klimatu Climatic conditions of Ukraine and possible consequences of climate warming. *Ahronom* [Agronomist], *1 (15)*. 8–11 [in Ukrainian].
4. Polovyi, A. (2010). Climate change for the good?. *Silski visti* [Rural news], *9 (112)*. 2 [in Ukrainian].
5. Pysarenko, P. V., Mishukova, L. S. (2020). Water consumption of winter wheat. *Ahrarni innovatsii* [Agricultural innovations], *1*. 63–68. DOI: 10.32848/agrar.innov. 2020.1.10 [in Ukrainian].
6. Solodushko, M. M,. Petrushak, V. Ya., Hladka, A. V., Sereda, I. I. (2010). Stocks of productive moisture in the soil after the restoration of spring vegetation and yield of winter wheat depending on growing conditions. *Biuleten Instytutu zernovoho hospodarstva* [Bulletin of the Institute of Grain Management], *38*. 29–33 [in Ukrainian].
7. Solodushko, M. M. (2024). Moisture availability and yield of winter wheat depending on predecessors in the Northern Steppe zone. *Zernovi kultury* [Cereal crops], *8*. 1. 84–91. https://doi.org/10.31867/2523-4544/0315 [in Ukrainian].
8. Zinchenko, O. I., Korotieiev, A. V., Kalenska, S. M. et al. (2008). Roslynnytstvo [Plant growing] / O. I. Zinchenka Ed. Praktykum. Vinnytsia: Nova Knyha Ed., 536 [in Ukrainian].
9. Lykhochvor, V. V., Petrychenko, V. F., Ivashchuk, P. V. (2008). Zernovyrobnytstvo [Agriculture]. Lviv: NVF «Ukrainski tekhnolohii». [in Ukrainian].
10. Cherenkov, A. V., Nesterets, V. H., Solodushko, M. M., Krotinov, I. V., Kobos, I. O. (2018). The influence of agroecological and technological factors on the formation of winter wheat yield in the southeastern Steppe. *Visnyk ahrarnoi nauky* [Bulletin of Agricultural Science], *5*. 18–26 [in Ukrainian].
11. Naukovi osnovy ahropromyslovoho vyrobnytstva v zoni Stepu Ukrainy [Scientific foundations of agroindustrial production in the Steppe zone of Ukraine (2004). / Zubets, M. V. (Ed.) et al. Kyiv: Ahrarna nauka, 2004. (pp. 15–18). [in Ukrainian].
12. Bondarenko, V. Y., Sobko, A. A., Hodulyan, Y. S. et al. (1977). Ozymaia pshenytsa v Stepy [Winter wheat in the Steppes] / Remeslo, V. N. (Ed.) et al.]. Kyiv: Urozhai. (pp. 239–252). [in Russian].
13. Netys, Y. T. (2009). Critical moisture for winter wheat. *Zerno* [Grain], *1*. 41–46 [in Ukrainian].
14. Hamaiunova, V. V., Panfilov, A. V., Hlushko, T. V. (2019). Importance of nutrition optimization and variety characteristics in the effective use of moisture by winter wheat in the conditions of the Northern Steppe of Ukraine. *Tavriiskyi naukovyi visnyk* [Tavria Scientific Bulletin], *107*. 22–28 [in Ukrainian].
15. Kyryliuk, V. P. (2018). Dynamika zapasiv produktyvnoi volohy i vodospozhyvannia pshenytsi ozymoi v umovakh Pravoberezhnoho Lisostepu Ukrainy [Dynamics of reserves of productive moisture and water consumption of winter wheat in the conditions of the Right Bank Forest Steppe of Ukraine]. *Visnyk Umanskoho natsionalnoho universytetu sadivnytstva* [Bulletin of the Uman National University of Horticulture], *1*. 9–15. *Access mode: http://nbuv.gov.ua/UJRN/vumnuc_2018_1_4* [in Ukrainian].
16. Zaiets, S. O., Netis, V. I. (2013). Water consumption of grain crops and soybeans depending on the conditions of moisture availability. *Zroshuvane zemlerobstvo* [Irrigated agriculture], *59*. 30–34 [in Ukrainian].
17. Krukivska, A. V. (2008). Agroclimatic assessment of moisture supply conditions of the main grain crops in Ukraine. *Ukrainskyi hidrometeorolohichnyi zhurnal* [Ukrainian Hydrometeorological Journal], *3*. 109–116 [in Ukrainian].
18. Hudz, V. P. (2010). Ekolohichni problemy zemlerobstva: Pidruchnyk [Ecological problems of agriculture: Textbook]. Zhytomyr: «Zhytomyrskyi natsionalnyi ahroekolohichnyi universytet» Ed. [in Ukrainian].
19. Shykula, N. K., Nazarenko, H. V. (1990). Minimalnaya obrabotka chernozemov i vosproyzvodstvo ikh plodorodiya [Minimal cultivation of chernozems and reproduction of their fertility]. Moskva: Ahropromyzdat, 320 [in Russian].
20. Zaiets, S. O., Muzyka, V. Ye., Nyzheholenko, V. M., Rudik, O. L. (2021). Assessment of the adaptive capacity and stability of winter soft wheat varieties under different conditions of moisture availability in the south of Ukraine. *Zroshuvane zemlerobstvo* [Irrigated agriculture], *76*. 17–21. DOI: 10.328 48/0135-2369.2021.76.3 [in Ukrainian].
21. Petr, Y., Cherny, V., Hrushka, L. (1984). Formirovaniye urozhaya osnovnykh selskokhozyaystvennykh kultur [Formation of the harvest of the main agricultural crops] / Blahoveshchenskaia, Z. K. transl. Moskva: Kolos. [in Russian].
22. Shapoval, I. S. (2002). Soil water regime depending on the saturation of crop rotations with grain crops. *Zbirnyk naukovykh prats Instytutu zemlerobstva UAAN* [Collection of scientific papers of the Institute of Agriculture of the Ukrainian Academy of Sciences],*1*. 44–47 [in Ukrainian].
23. Litvinov, D. V. (2007). The dynamics of productive moisture in the soil during the cultivation of grain ear crop. Zbirnyk naukovykh prats NNTS «Instytut zemlerobstva UAAN» [Collection of scientific papers of the National Scientific Center «Institute of Agriculture of the Ukrainian Academy of Sciences»]. Kyiv: EKMO. (pp. 3–4, 34–38). [in Ukrainian].
24. Kaminskyi, V. F., Hanhur, V. V. (2018). Dynamics of productive moisture in the soil during the cultivation of winter wheat in crop rotations of the Left-Bank Forest-Steppe of Ukraine. *Visnyk Poltavskoi derzhavnoi ahrarnoi akademii* [Bulletin of the Poltava State Agrarian Academy], *3*. 11–14. DOI: 10.31210/ visnyk2018.03.01 [in Ukrainian].
25. Netis, I. T. (2011). Pshenytsia ozyma na pivdni Ukrainy [Winter wheat in southern Ukraine]: monohrafiia. Kherson: OldiPlius. [in Ukrainian].
26. Priadko, Yu. M. (2014). Features of growth and development of winter wheat plants in the autumn vegetation period depending on predecessors and sowing

dates. *Biuleten Instytutu silskoho hospodarstva stepovoi zony NAAN Ukrainy* [Bulletin of the Institute of Agriculture of the Steppe Zone of the NAAS of Ukraine], *7*. 143–147 [in Ukrainian].

27. Romanenko, O. L., Konova, S. R., Solodushko, M. M., Baloshenko, S. V. (2015). The influence of lopment of winter wheat at different sowing dates. *Ahropromyslove vyrobnytstvo Polissia* [Agro-industrial production of Polissya], *6*. 14–20 [in Ukrainian].
29. Lytvynenko, M. A. (2016). Creation of varieties of soft winter wheat (*Triticum aestivum* L.), adapted to climate changes in Southern Ukraine.*Zbirnyk naukovykh prats Selektsiino-henetychnoho instytutu Natsionalnoho tsentru nasinnieznavstva ta sortovyvchennia* [Collection of scientific papers of the Breeding and Genetic Institute of the National Center for Seed Science and Variety Research], *2 (67)*. 36–53. URL: http://nbuv.gov.ua/UJRN/Znpsgi_2016_27_5 [in Ukrainian].
30. Netis, I. (2016). Soil water regime on winter wheat crops in the Southern Steppe conditions. *Ahrobiznes sohodni* [Agribusiness today], *11*. URL: https://agro-business.com.ua [in Ukrainian].
31. Dospekhov, B. A. (1985). *Metodika polevogo opyta s osnovami statisticheskoy obrabotki rezultatov issledovaniy* [Methodology of field experience with the agroecological factors on the yield of winter wheat in the steppe zone of Ukraine. *Ahroekolohichnyi zhurnal* [Agroecological journal], *1*. 106–114 [in Ukrainian].
28. Vorona, L. I., Storozhuk, V. V., Tkachuk, V. P., Shvaika, O. V., Ishchuk, O. V. (2013). Weather conditions of the autumn growing season and the deve- basics of statistical processing of research results] (5thed. rev.). Moscow: Ahropromizdat. [in Russian].
32. Tsykov, V. S., Pickush, G. R. (1983). *Metodicheskie rekomendacii po provedeniyu polevykh opytov s zernovymi, zernobobovymi i kormovymi kulturami* [Methodical recommendations on caring out the field tests with cereals, legumes and feed crops]. Dnepropetrovsk, 46 p. [in Ukrainian].
33. Romanenko, O. L., Konova, S. R., Solodushko, M. M., Baloshenko, S. V. (2015). Soil moisture availability and productivity of winter wheat plants of various ages in the southern steppe zone. *Visnyk Tsentru naukovoho zabezpechennia APV Kharkivskoi oblasti* [Bulletin of the Center for Scientific Support of APV of Kharkiv Region], *18*. 87–95. [in Ukrainian].
34. Kovalenko, A. M., Kovalenko, O. A. (2016). Features of sowing winter wheat in dry autumn in the Southern Steppe under climate change conditions. *Zroshuvane zemlerobstvo* [Irrigated agriculture], *6*. 56–59 [in Ukrainian].

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Солодушко М. М., Солодушко В. П., Гасанова І. І., Завалипіч Н. О. Запаси вологи в грунті та розвиток рослин пшениці озимої протягом осінньої вегетації в зоні Північного Степу України. *Зернові культури. 2024. 8 (2). 289–296.*

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Актуальність. Знаючи тенденції та закономірності впливу атмосферних явищ, зокрема температури повітря та кількості опадів, на формування окремих елементів структури врожаю пшениці озимої, є велика ймовірність уникнути або ж значно пом'якшити негативну дію того чи іншого погодного фактору, що в окремих випадках відіграє вирішальну роль у забезпеченні появи дружних сходів, розвитку рослин восени та їх стану перед зимівлею. **Мета** проведених досліджень полягала у визначенні впливу погодних умов осіннього періоду на вологозабезпечення грунту та стан рослин пшениці озимої перед зимівлею, яка вирощується після соняшника в зоні Північного Степу України. **Матеріали і методи.** Вивчення та аналіз проблемних питань проводилися впродовж 2019–2024 рр. на Синельниківській селекційно-дослідній станції в сівозміні лабораторії агробіологічних ресурсів озимих зернових культур ДУ Інститут зернових культур НААН. Технологія вирощування пшениці озимої – загальноприйнята для північної частини Степу України. Відбір зразків грунту та рослин проводився згідно з існуючими рекомендаціями. **Результати.** Погодні умови впродовж осінньої вегетації значною мірою обумовлювали стан посівів пшениці озимої на початку зимового періоду. Протягом 2019–2024 рр. за вересень – листопад середні значення температури повітря та кількості опадів склали відповідно 10,8 °C та 114,6 мм, що виявилося на 1,6 °C вище та на 2,4 мм менше середньої багаторічної норми. Підвищений температурний режим та тривала відсутність опадів призводили майже щороку до критичного зниження запасів продуктивної вологи в грунті на час сівби пшениці озимої, які в середньому складали у шарі грунту 0–10 см лише 2 мм, 0–20 см – 4 мм, 0–50 см – 10 мм, 0–100 см – 17 мм, що загалом становило 21–25 % середніх багаторічних значень. Впродовж осіннього періоду атмосферні опади не забезпечували потреби рослин у волозі, середня кількість якої на час припинення їх осінньої вегетації в орному та метровому шарах грунту складала відповідно лише 16 мм і 45 мм, або 50 та 44 % середньої багаторічної норми. В результаті цього біометричні параметри рослин пшениці озимої перед зимівлею в більшості років не відповідали оптимальним значенням, які б насамперед забезпечували її високу морозостійкість – рослини мали висоту 13–15 см, налічували в середньому 1,1–1,4 пагони та 1,8–2,7 вузлових корінці. **Висновки.** Встановлено, що вологозабезпеченість грунту протягом осіннього періоду в більшості років не задовольняла потреби у волозі рослин пшениці озимої, які в результаті цього розпочинали зимівлю у відносно слабкому морфофізіологічному стані. Проте, підвищена температура повітря впродовж календарної зими дозволила озимині оптимальних строків сівби успішно, практично без втрат, завершити зимовий період.

Ключові слова: *пшениця озима, погодні умови, запаси вологи в грунті, осіння вегетація, стан рослин*