

INFLUENCE OF GLOBAL WARMING ON HYDROTHERMAL INDICATORS AND OVERWINTERING OF WINTER CEREALS IN THE CONDITIONS OF PRYSYVASHSHA

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Topicality. Climate change due to global warming determines important and relevant areas of research activities at the current stage of agricultural development. Climate change affects the potential of natural resources therefore the limits of these changes are taken into account when determining the ways of agricultural production development. **Purpose.** To determine the impact of global warming as a result of changing climatic conditions on the overwintering of winter cereals in Prysyvashsha. **Materials and Methods.** The research materials were long-term observations of the basic climatic indicators at the Henichesk Experimental Station of the SE Institute of Grain Crops of NAAS. **Results.** Changes of the main climatic indicators against the background of global warming in Prysyvashsha for the 2004–2020 were analyzed. During 2015–2018, the soil freezing depth and the minimum temperature at the depth of the tillering node of winter cereals during the winter period were investigated. An increase in the average annual air temperature was recorded, which caused a decrease in the soil freezing depth and an increase in its temperature at the depth of the tillering node and shortening of the winter period. **Conclusions.** According to the results of the study, there is an essential need to find more optimal dates for sowing winter wheat and barley as one of the key segments of agrotechnical measures, which provides better adaptation of winter crops and increase their productivity when grown in new environmental conditions in the arid Steppe zone of Ukraine.

Key words: global warming, climate change, air temperature, soil temperature, precipitation, winter wheat, winter barley, sowing dates, depth of soil freezing

Introduction. Currently, one of the most important and urgent areas of research and development at the present stage of agricultural development is the problem of climate change in general and global warming in particular.

Climate change also leads to changes in natural resources, and therefore defining their boundaries has always been of great importance in agriculture and other industries closely related to weather and climate [1–3]. In the agricultural sector, the yield of agricultural products is largely determined by the climate. Thus, natural resources not only determine the average level of crop yields, but also have a significant impact on the production cost [4].

In the Dry Steppe zone, which is a risky agriculture zone, the main limiting factor for yields is the moisture supply of crops [2, 4, 5].

Global climate change depends on many factors. First of all, it is the solar activity cycles and human activity. The first factor is uncon-

trollable, while the second factor, we have a direct impact and can regulate it.

As we know, water is one of the main vital factors for all organisms, including plants. Optimal water supply to plants in development stages is the essential condition for high yield of field crops. Water is not only a nutrient substrate for plants, but also a chain that ensures their connection with the environment [6, 7]. Most nutrients are supplied to plants through the root system in the form of soil ion solution. The moisture deficit in the soil leads not only to a lack of water supply to the organism, but also reduces the absorption of nutrients by plants [7, 8]. Therefore, the study of the predicted moisture supply of field crops at different development stages has great economic importance, and research in this area is relevant.

These factors necessitate revision of the regulatory parameters of agrotechnical practices for growing crops in the Prysyvashsha area.

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First of all, the sowing dates of winter soft wheat (*Triticum aestivum* L.) and winter barley (*Hordeum vulgare* L.) need to be revised, since these crops are occupying up to 55 % of the sown area and are the main crops for grain production in the region. In this regard, the expansion of pea (*Pisum sativum* L.) crops in the Prysyvashshia as one of the best non-fallow predecessors for winter cereals, which in some years provides grain productivity equal to black fallow, should also be considered.

Purpose. To determine the impact of global warming on climate change in the Prysyvashshia, to consider their dynamics and to identify the issues that arise for winter grain crop production, especially during the overwintering period.

Materials and Methods. The research was carried out at the Henichesk Experimental Station (HES) of the State Enterprise of the In-

stitute of Cereals of NAAS. Meteorological observations were carried out on the meteorological post of the HES and the Henichesk Hydrometeorological Station. The precipitation amount was determined by using a precipitation gauge. Temperature measurements were made according to the methodology [9]. For the comparative analysis of hydrothermal parameters, the results of the studies conducted at the HES were used.

The terrain is levelled due to its terraced origin. The plain has a low slope in the southern and south-eastern directions, is characterised by drainagelessness and presence of closed flat lowlands – hollows and depressions of various sizes. The soil is represented by heavy loamy, chestnut brown, sodic soils with various degrees of alkalinity (Table 1).

The soil is characterised by a strong physical alkalinity, structureless topsoil and strong

Table 1. Characteristics of arable soil layer

Area, ha	Mechanical composition	Humus horizon thickness	Arable layer, cm	Humus content, %	Content, mg/100 g of soil			Ph of salt extract
					N-NO ₃	P ₂ O ₅	K ₂ O	
1131	Heavy loams	80 cm	29	2.4	180	125.1	2200–2500	7.78
216	Heavy loams	55 cm	24	2.4	200	120	2100	7.6

compaction of the illuvial horizons with a low content of absorbed sodium. The humus content in the arable layer ranges from 2.5 (sodic soils) to 4.2 % (dark chestnut soils). The carbonate layer located at a depth of 35–46 cm in sodic soils and 40–50 cm in chestnut medium-sodic soils. Groundwater is highly mineralised and is located at a depth of 2.5–5 metres. The relief is characterised by a flat surface with a general slope towards Syvash. Chestnut heavy loamy soils are medium and strongly alkaline in combination with sodic soils on carbonate loess with salt accumulations.

Results and Discussion. Precipitation and temperature measurements were carried out in 2004–2020. The results of the data analysis show that an increasing average annual temperature of 1.4–1.6 °C causes the displacement of climatic zones from south to north, which leads to a decrease in the hydrothermal coefficient and the expansion of the risky agriculture zone. At the same time, there is a change in the

life cycle and the spread of new types of weeds, pests and diseases.

Other negative impacts of global warming include instability in the passage of seasons, which are characterised by large temperature amplitude with a sharp change, both during the day and in the seasons, which causes plant stress.

Comparing the data for 2004–2020 and the baseline period [12], we see large discrepancies between them. First of all, the difference in annual averages, temperature, and precipitation draws attention (Table 2). This shows a clear trend towards an increasing average annual temperature. The climate average is 10.33 °C, but it increased significantly in 2004–2021, and reached 11.8 °C, which is 1.47 °C higher than the climate average.

The average annual precipitation in the Steppe of Ukraine requires a lot of attention. We can see that the annual precipitation has decreased by 22.9 mm from 398 mm according to the

Table 2. Changes of air temperature and precipitation in the Prysyvashshia

Month	Average monthly temperature and precipitation			
	baseline climatic period		post-baseline climatic period (2004–2020)	
	t °C	mm	t °C	mm
I	-2.3	35.0	-0.9	36.6
II	-1.6	32.0	-0.2	26.8
III	2.0	32.0	4.3	23.3
IV	9.3	30.0	10.6	25.1
V	16.1	35.0	17.7	46.4
VI	20.6	42.0	22.7	37.1
VII	22.9	39.0	24.8	30.1
VIII	22.1	27.0	23.4	24.0
IX	17.3	31.0	18.8	37.2
X	11.0	25.0	12.0	25.4
XI	5.4	32.0	6.3	27.2
XII	1.1	38.0	2.2	35.9
Average for year	10.33	398.0	11.8	375.1

climate norm to 375.1 mm as of the current state.

In addition, changes in the distribution of precipitation and temperature over the year are essential, as precipitation has different assimilation rates in different periods of the year, and an average monthly temperature increase of 1 °C in January does not equate to 1 °C increase in July.

Compared to the baseline period, the largest changes in the average monthly temperature of more than 2.0 °C were in March and June.

There are also changes in the precipitation distribution. According to the average climatic norm, June and July were the wettest months. At present, this peak of precipitation has shifted a month earlier, and the wettest months are May and June, which is important for water supply to winter crops in the most critical development stages.

In addition, it should be noted that according to the average climatic data, the distribution of precipitation throughout the year was uniform, and in modern conditions, there is a significant irregularity. Therefore, the preservation of soil moisture by means of agrotechnical practices in the winter cereals cultivation remains relevant.

The overwintering period of winter grain crops usually continues for 90 to 115 days in the Southern Steppe of Ukraine, and rarely for 120 days. In this period, the plants are influenced by negative natural factors, namely low temperatures, ice crust, strong winds, which, combined

with the lack of snow cover, causes dust storms. It is difficult to predict the negative impact of various climatic phenomena, and each of them can cause significant damage to winter crops and even their death.

Over the past 8 years, in winter, an important feature of winter crops was the one or two temporary growth resumption for a total period of 12–20 days. Examination of winter wheat crops at different development stages since autumn showed that after the spring growth resumption, no damage from low temperatures (-8...-10 °C) was detected on plants in the stages of the pip, 3 leaves and full tillering. The temporary growth resumption resulted in the beginning of the stem elongation stage in overgrown plants, and the death of primordial spikelets was noted, mostly on the main stem.

According to our observations, in 2015–2016, the winter period was ultra-short and lasted only 70 days, which is significantly less than the long-term average. It should be noted that the air temperature at this time exceeded the monthly average for December by 1.9 °C; in January by 0.1 °C and in February by 5.4 °C, and thus significantly improved the conditions for plants to survive the winter period.

Over the years of study, the longest winter period was recorded in 2017–2018, which lasted 103 days, while the period of 2016–2017 was slightly shorter and lasted 83 days. In terms of temperature, the coldest period was 2016–2017,

and the abnormally warmest was 2017–2018.

The soil freezing depth and temperature decrease to the minimum values at the tillering node depth during December–February were closely related to the air temperature, snow cover thickness, predecessor and sowing method.

During the research in 2015–2018, excavations on winter wheat crops in the winter

months after the coldest periods to determine the maximum depth of soil freezing showed that in January 2017, under black fallow, it was the deepest and amounted to 20.1–20.3 cm, while under non-fallow predecessors (grain sorghum and sunflower) the soil froze to a shallower depth and amounted to 16.2–18.4 cm and 17.0–18.6 cm, respectively (Table 3).

Table 3. Influence of air temperature on the soil freezing depth and its minimum indicators in the tillering node zone on winter wheat crops depending on the predecessors and sowing methods, 2015–2018

Indicator	Month	Predecessor					
		black fallow		sorghum for grain		sunflower	
		sowing methods					
		traditional sowing	direct sowing	traditional sowing	direct sowing	traditional sowing	direct sowing
Average monthly air temperature, °C	December	+ 2.4		+ 2.4		+ 2.4	
	January	- 1.6		- 1.6		- 1.6	
	February	+ 0.9		+ 0.9		+ 0.9	
Maximum freezing depth, cm	December	5.9	5.9	5.4	4.1	5.2	4.4
	January	14.3	14.1	13.3	11.2	13.5	12.2
	February	15.7	15.6	14.6	12.6	14.7	13.3
Minimum temperature at the depth (3.5 cm) of the tillering node, °C	December	- 2.3	- 2.1	- 1.8	- 1.4	- 1.9	- 1.5
	January	- 5.5	- 5.5	- 4.6	- 3.0	- 5.0	- 4.6
	February	- 4.7	- 4.6	- 4.3	- 3.6	- 4.4	- 3.9

During the winter periods, on average over three years, the deepest soil freezing was recorded in February.

The tillering node is the most important part of the winter cereal plant for overwintering.

Death of the tillering node causes the death of the entire plant. Usually, the tillering node is affected by soil temperatures below 0 °C at a depth of its occurrence of 3.0–3.5 cm.

According to the three-year data, the minimum temperature at the depth of the tillering node in December for black fallow was insignificant and ranged from -2.1 °C to -2.3 °C, for grain sorghum from -1.4 °C to -1.8 °C and for sunflower from -1.5 °C to -1.9 °C. In January, a more significant decrease in temperature was noted, temperatures ranged from -5.5 °C, -3.0 °C, -4.6 °C and -4.6 °C, -5.0 °C, and slightly higher temperatures were recorded in February, with temperatures from -4.6 °C to 4.7 °C, from -3.6 °C to 4.0 °C and from -3.9 °C to 4.4 °C, respectively.

Thus, in 2015–2018, overwintering of winter wheat crops in the conditions of Prysyvashshia was satisfactory due to the low soil temperature at the depth of the tillering node, which was not critical. Our further observations found that overwintering of winter wheat and winter barley in 2019–2022 were similar, which is a direct consequence of climate change, in particular, the global temperature increase.

Conclusions

The analysis of air temperature and precipitation data for 2004–2020 revealed that the air temperature increased by 1.47 °C, while precipitation decreased by 22.9 mm in the Prysyvashshia. Climate change has led to a decrease in the depth of soil freezing and an increase in temperature at the depth of the tillering node. As a result, overwintering conditions for winter crops have improved. Prolongation of autumn growth season amid global warming forces to revise sowing dates and structure of winter crops.

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Костиця І. В.¹, Остапенко М. А.¹, Бондаренко М. К.² Вплив потепління на гідротермічні показники та перезимівлю озимих зернових в умовах Присивашшя.

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Актуальність. Проблема кліматичних змін у наслідок глобального потепління, одна за важливих та актуальних напрямків науково-дослідної діяльності на сучасному етапі розвитку сільського господарства. Зміна клімату тягне за собою зміну потенціалу природних ресурсів і тому визначення їх меж завжди береться до уваги при визначенні напрямку ведення аграрного виробництва. **Мета дослідження.** Визначити, як вплинуло глобальне потепління через зміну кліматичні умови на проходження зимового періоду озимими зерновими культурами в Присивашші. **Матеріали та методи дослідження.** Матеріалами дослідження були багаторічні спостереження за основними кліматичними показниками на Генічеській дослідній станції ДУ ІЗК НААН України. **Результати та обговорення.** Було проаналізовано зміни основних кліматичних показників за період 2004–2020 роки в Присивашші на фоні глобального потепління та досліджені впродовж 2015–2018 рр. глибина промерзання ґрунту і мінімальні значення температури на глибині залягання вузла кущення озимих зернових культур під час проходження зимового періоду. Зафіксовано зростання середньорічної температури повітря, що призвело до зменшення глибини промерзання ґрунту та підвищення його температури на глибині вузла кущення. **Висновки.** Посилаючись на одержані дані виникла вагома необхідність пошуку більш оптимальних строків сівби пшениці, ячменю озимих, як одного з ключових сегментів агротехнічних заходів, що забезпечує кращу адаптацію посівів озимини і зростання їх продуктивності при вирощуванні в нових умовах природного середовища в зоні сухого Степу України.

Ключові слова. Глобальне потепління, зміна клімату, температура повітря, температура ґрунту, опади, пшениця озима, ячмінь озимий, строк сівби, глибина промерзання ґрунту