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THE DEPENDENCE OF THE DURATION OF THE GERMINATION PHASE OF SPRING BARLEY ON THE TEMPERATURE REGIME OF THE SOIL

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Abstract

The article draws attention to a particularly sensitive period of spring barley development, which directly relates to the germination phase. On the basis of the obtained data, it was established that the germination phase of spring barley during the studied sowing dates is 10.03; 20.03; 30.03; 9.04. 19.04 is characterized by a decrease in the duration of the period from sowing to seedlings for each subsequent sowing period. It was established that soil temperature is an important factor influencing the duration of spring barley germination. Correlation coefficient r = -0.97 was established accordingly. The dependence of the onset of the tillering phase in spring barley plants on the sowing dates was revealed. Accordingly, the barley plants of the first sowing period entered the tillering phase earlier by 13-15 days compared to the third sowing period and by 22-25 days compared to the April 9 sowing period. This is a rather important advantage, since the duration of the tillering phase will be the longest in barley plants of the first sowing period, which will contribute to the implementation of the first and second elements of the grain yield structure.

Key words: *spring barley, sowing time, germination duration, soil temperature regime, seedlings, tillering of plants.*

INTRODUCTION

Barley is a food, technical and fodder crop (Bomba et al., 2020). It belongs to the oldest and most famous diverse grain crops, it is grown all over the world in large quantities on large areas (Kasatkina et al., 2018; Gorobets et al., 2020). Barley is especially important as a fodder crop (Petrychenko et al., 2018). Dry matter contains 70-85% of total carbohydrates, 10-12% – protein, 2-3% – fats, 2-4% – minerals and 1-2% – other substances. The volume of world grain production fluctuates depending on the year in the range of 135-150 million tons.

Grown barley grain is also used for the production of food products – flour, pearl barley, hollandaise, barley groats. Pearl barley is a whole grain from which the flower film has been removed. Hollanda is a cereal in the form of a ball of barley grain, from which the film is removed and the top and the lower germ part of the grain are freed. Barley groats – finely ground, polished barley.

In addition, barley grain is an important raw material for the production of brewing and vodka malt (Toma et al., 2024; Kostadinova, 2023). In order to obtain malting barley, it is necessary to comply with the special requirements of the cultivation technology, which is supposed to achieve high technological qualities of the grain. In particular, issues of biochemical quality are important, namely ensuring the appropriate parameters of grain protein content, extractability, diastatic force, Kolbach number, friability, beta glucan content (Buturlym et al., 2021; Puzik, 2019).

Numerous studies confirm the centuries-old experience of using barley for the purpose of treatment (Rybalka et al., 2016). Swedish scientists found out that barley groats protect against type 2 diabetes, obesity, and some diseases of the cardiovascular system. It is known that a decoction of crushed barley groats treats the gastrointestinal tract (ulcers, inflammation of the intestines), strong cough, acts as a diuretic, as well as a sedative, antispasmodic, is characterized by enveloping and expectorant properties, and improves metabolism. It is believed that barley decoctions and porridges remove radionuclides from the body and lower cholesterol. A decoction of barley grain in a film is useful for vision, liver, kidneys, helps with headaches, infectious diseases (fungus, pneumonia, pyelonephritis, hepatitis, sinusitis), helps dissolve kidney stones. Therefore, barley is given the role of a healing plant.

Barley is rich in vitamins. These physiologically active substances are localized in the germ and the aleurone layer of the grain. Among B vitamins, barley grain contains vitamin B_1 (thiamine), vitamin B_2 (riboflavin), B_6 (pyridoxine), PP (nicotinic acid). Vitamin H (biotin), pantothenic acid, folic acid and α-aminobenzoic acid are also present. Barley is also rich in vitamin C, the accumulation of which is greatly facilitated by the high level of provision of potassium fertilizers. Vitamin E in barley is contained in the form of isomers α, β, γ, δ – tocopherol and tocotrienoly, and exhibits antioxidant properties.

Regarding the historical reference, very little information is given about how barley was grown in ancient times. The first written documents about the cultivation of barley are laid out on a fragment of a board around 1700 BC in Mesopotamia. On 109 lines, a significant amount of agronomic advice is indicated in cuneiform script, which touches on the issues of soil preparation, plowing, sowing, harvesting and seed sorting.

Today there is a different view of historical reality. The scientific sensation is that there were settlements on the territory of modern Ukraine even in Mesolithic times. The cultivated plant grown by our distant ancestors was barley. Cultivated cereals began to spread precisely from the Dnieper region. This was proven by radiocarbon analysis of artifacts found at the bottom of the Black Sea as a result of research conducted in 2012 by a deep-sea archaeological expedition under the auspices of UNESCO. 26,000 years before the end of the Neolithic, the level of the Black Sea rose by 100 m and flooded the inhabited shelf. Therefore, it can be assumed that many years before our era, on the right-bank part of the territory of our Ukraine, people mastered household chores, including barley cultivation (Horash et al., 2019).

So, scientific evidence proves that the cultivation of flaky barley began on the territory of modern Ukraine earlier than in the Middle East and before the development of agricultural culture by Western Europe.

Today, despite the ancient past, barley cultivation, starting with our distant ancestors, constantly poses new and new challenges to humanity.

The production of plant products, in particular, barley grain, depends on many factors (Ishchenko, 2021; Hospodarenko et al., 2015; Gavriliuk, 2009).

Production volumes are primarily influenced by market conditions and the need for a specific type of technical raw material (Radishchuk, 2015). At the same time, not only the biological features of barley plants as a culture are important, but also the perfection of the growing technology.

Agricultural cultivation of spring barley is severely limited by various abiotic and biotic stress factors (Mittler, 2006; Kosova et al., 2014). Abiotic factors include various factors of environmental conditions, in particular, precipitation, solar radiation, temperature regime, air flows (Kosová et al., 2013). Biotic factors include pathogenic microflora, harmful organisms, living organisms that negatively affect the growth and development of plants (Yang et al., 2013). These are viruses, fungi, bacteria and insects that damage plants. These factors can reduce the yield of spring barley grain up to 50% (Basu et al., 2016; Lamaoui et al., 2018).

In order to obtain a high level of yield of spring barley, various new agronomic practices aimed at creating optimal conditions for the growth and development of plants are being introduced. That is why research aimed at evaluating new approaches and methods of increasing the yield of agricultural crops, including spring barley, is an urgent task of our time.

To maximize the biological productivity potential of varieties and hybrids of agricultural crops, it is necessary to have thorough knowledge of all the factors on which the potential realization process depends.

From the point of view of modernity, the intensive technology of growing agricultural crops should be considered as a technology that provides the opportunity to realize the potential of the external environment of the ecosystem to the greatest extent, under the condition of ensuring the effective implementation of the potential of the biological factor at the lowest costs of intensification means.

The agricultural ecosystem in crop production does not fundamentally differ from the ecosystem, which is natural, as it is characterized by the same features, the same laws, all the main elements, dependencies and properties exist in it. The main important components of the agroecosystem include the external environment (vegetation factors) and productivity factors (producers, that is, field crops that ensure the production of organic matter).

Intensification of crop production by technological factors is a costly part of growing agricultural crops. There are sufficiently significant reserves associated with other factors, in particular with vegetation factors, the main of which include solar radiation and positive, effective and active temperatures dependent on it, which ensure the heat demand of plants.

Ukraine has all the conditions for the effective development of agriculture, namely, fertile soils, favorable climatic conditions (Vozniuk et al., 2023; Bondar et al., 2023).

In literary sources, it is noted about the trend of climate change regarding the increase in the average annual air temperature, and therefore by the end of the 21st century, an increase in temperature by 2-4°C is expected throughout Ukraine (Yatsyuk et al., 2021; Christidis et al., 2021). As is known from literary sources, climate change can affect both yield and grain quality of agricultural crops, including barley (Ko et al., 2019; Kim et al., 2022).

Today, the agroclimatic resource for growing spring barley in the conditions of the Western forest-steppe of Ukraine has undergone changes due to the earlier onset of heat. This makes it possible to start spring field work 25-30 days earlier, to carry out sowing of early spring grain crops. This actually creates new additional levels of energy resources for their use in agricultural technologies. Technologically, it is possible to reach different levels of energy resources thanks to different sowing periods, where the potential of the agro-climatic resource, its availability in terms of volume will depend on the degree of favorability. The explanation of this regularity lies in the correspondence of the constituent resources to the biological needs of growth and development. In this aspect, attention should be paid to global climate changes. The climate of the Western forest-steppe changes from moderately continental to sharply continental. The probability of dry years, hydrological droughts, moisture deficit during crop formation has increased. With reference to this, shifting the spring barley sowing dates from the traditional ones at the beginning of April to earlier ones is a justified and expedient measure in cultivation technology.

Therefore, the question of the ecological expediency of crop production in order to ensure additional energy accumulation by the grown crop or other categories to obtain a higher level of productivity under the conditions of the same resources, both technical and anthropogenic, is an important step in the development of technology. Such directions and directions of scientific research will reveal quite significant reserves of the functioning of the agroecosystem at the higher energy levels of the ecosystem.

The intensity of development of the agro-ecosystem of field crops and their productivity depends on the arrival of two energy types, namely radiant and additional, which is necessary for the maximum use of solar radiation. Practically, the task that relies on the technology can be formulated as follows: obtaining the maximum productivity of crops with minimal expenditure of additional energy.

Solving such tasks consists in ensuring the optimization of the elements of crop production technologies by adapting them to changes in existing conditions not only by selecting crops and appropriate varieties, but also by the entire complex of technological measures.

In modern intensive systems of growing grain crops, there is a demand for increased attention to plants as a biological means of production. Varieties of spring barley are characterized by a number of productive, biological and technological properties. Special importance is given to biological properties and features in connection with the task of growing technology to maximize the potential of crop productivity (Horash et al., 2020; Horash, 2017). A number of scientific studies have established that the optimization of plant growth and development in the process of growing agricultural crops cannot be achieved without paying special attention not only to the biological object, as the main factor of technology, but also to vegetation factors (Horash et al., 2020; Horash, 2017). In this regard, in the analysis of the energy efficiency of growing technologies, attention is paid to the processes of interaction of the biological factor, that is, the variety or hybrid and vegetation factors, taking into account the generally accepted requirements of the culture during cultivation.

Barley is characterized by a wide variety of forms adapted to different soil and climatic conditions. The high adaptability of this culture ensured its spread on all continents of the globe. Insignificant demand for heat and a short growing season make it possible to grow barley in the northern areas of agriculture.

Barley is characterized by an accelerated pace of development. This property ensures that the culture is indispensable not only in the northern regions of Europe, but also in the arid regions of the Asian continent. Better than other crops, barley uses the reserves of productive moisture accumulated in the cold period of the year and has time to form a crop before the onset of dry and hot weather in the second half of summer. Thanks to this, barley in arid growing zones provides higher and more stable yields than wheat and oats. Many varieties of barley are heat-resistant and resistant to soil salinity. Among the varieties of barley there are those that can be sown both in winter and in spring, i.e. two-handed. Accordingly, there are varieties of winter and spring forms, but these are not systematic units.

At the heart of the growing barley technology is the task of maximally realizing the potential of the culture. Accordingly, it is necessary to ensure: 1) the maximum efficiency of the biological factor – varietal parameter (category) and biological potential of seeds; 2) the maximum efficiency of agricultural methods – the process of sowing, application of mineral fertilizers, compliance with the favorable development of the row spacing and seeding rate.

Particular attention is currently being paid to the maximum effectiveness of the use of vegetation factors due to early sowing dates, the direction of placement of rows, uniformity of plant placement along the row, the favorability of the ecosystem to the biological requirements of the crop and variety (Tkachuk et al., 2018).

Special attention should be paid to the issue of growing spring barley in the conditions of the zone allocated for the favorable soil, climate and hydrological resources for the needs of the brewing industry.

According to calculations, the areas allocated for the cultivation of malting barley represented by chernozems amount to about 2 million hectares. As a result, the potential possibility of the allocated zone for the annual production of malting barley can be at least 2 million tons of grain.

The designated zone for the cultivation of malting barley is part of the fourth agricultural specialization zone of Ukraine – "Intensive beet cultivation, grain and fodder production", justified on the basis of objective compliance with the law of wide zoning (Polupan et al., 2005).

Soils play an important role during the germination of barley seeds. They are an important factor in ensuring the resistance of agricultural crops to climate changes (Cojocaru, 2020; Dehtiarov, 2023). The thermal properties of podzolized chernozem soils are characterized by temperatures that, in relation to plants, significantly affect the development of the root system (Dudar et al., 2022; Polupan et al., 2019).

An important factor in establishing optimal conditions for growing malting barley in Ukraine based on its capabilities is the radiation balance, which affects the temperature regime of the soil, adjacent air layers, evaporation and transpiration processes.

Barley is quite sensitive to soil fertility. This is explained by its biological properties. It has a root system with a low level of assimilation of hard-to-reach forms of nutrients from the soil and is characterized by a short period of intensive accumulation of nutrients. It produces high yields on fertile, structured, moderately cohesive loamy soils with a mechanical composition. The most suitable chernozems for it are deep and podzolized forest-steppe and steppe zones (Kononyuk et al., 1986).

It has been established that dark-colored soils contain more mobile forms of nitrogen, phosphorus, and potassium, which contributes to better plant development. An important role in heat accumulation by soils is played by their heat absorption capacity. Black soils reflect the sun's energy the least – 8%. The amount and quality of humus, which determine the color of the soil, as well as the granulometric composition, have the most significant effect on the heat-absorbing capacity of soils. Soils with a high humus content (chernozems) absorb 10-15% more radiation energy than soils with a low humus content. Accordingly, heat capacity is better in soils with a high content of humus. The amount and quality of humus also affect the volume heat capacity, the more humus in the soil, the more heat capacity it has (Polupan et al., 2019).

The thermal properties of soils are characterized by their temperatures, which in relation to plants significantly affect the development of the root system.

Deep medium-loam chernozems warm up earlier in time to a depth of 5 cm than dark gray podsolized medium-loam soils.

Due to their black color, high content of humus and good parametric characteristics in terms of particle size composition, black earth soils better absorb the energy of the sun, they retain heat for a long time, which is quite important in connection with the strategy of early sowing of spring barley and ensuring effective initial development already at the beginning of germination.

The annual amount of precipitation and the uniformity of its distribution during the growing season ensure the total water demand and correspond to the biological optimum of spring barley. The beginning of the vegetative period from 1.IV and the course of increasing positive temperatures with the effectiveness of technological measures to realize the biological potential of spring barley can contribute to the grain yield of at least 8-10 t/ha. According to the biological content of solar radiation, the conditions of the zone ensure the advantage of accumulation of carbohydrates in cereal crops, scattered radiation as part of the total is 50-52%. In general, the favorable conditions for productivity of spring barley in the designated growing zone are the highest in Ukraine and amount to 80-85%.

However, it should be noted that until recently, over a period of 10 years, two of them were such that ensured the implementation of field work in the first days of March, the rest ensured the beginning of spring field work in late March – early April. According to the observation of the duration of the period from 2014 to 2023, two of them, 2021 and 2022, were those years that, according to the conditions, contributed to the implementation of sowing field work in early April, for the remaining years, the arrival of heat contributed to the sowing of early grain crops in the first decade of March.

Barley seeds begin to germinate at a temperature of 1-2°C. However, under such conditions, the germination process is very slow. At a temperature of 4°C, the duration of seed germination takes from 5 to 7 days, at 10°C – 3 days, and at 16-19°C – 1-2 days. Accordingly, the duration of the sowing-emergence period depends on the soil temperature. The higher it is, the earlier the seedlings appear on the soil surface. However, the most favorable temperature at the beginning of barley development is 10-15°C, which is slightly less than the optimal parameters for seed germination, for which the indicators are 20-23°C. High temperature accelerates the development of plants by shortening the duration of the tillering phase, which causes a decrease in the productivity of the barley ear.

Germination of barley seeds is a complex biological process during which the formation of a seedling takes place from the very beginning. This is the first stage of the life cycle, which is characterized by the growth process. Conditions or factors such as heat, water, air and nutrients are necessary for normal germination. It is important to pay attention to the fact that germination occurs through the process of respiration, during which carbon dioxide is released and oxygen is absorbed.

Barley seedlings can withstand short-term frosts from 5 to 8°C. At lower temperatures, the tops of the leaves may be damaged (Shuvar et al., 2021).

The intensity of germination during this phenophase depends on the viability of the seed, its quality, where it is necessary to include the high energy of germination, the amount of energy resources concentrated in the endosperm, the enzymatic potential (enzymatic complex of cytase, enzymes that break down starch – α and β-amylases, proteolytic enzymes – proteases, phosphoric acid enzymes – phosphatases) grain weight, seed wrapping depth during sowing. To what extent the germination of barley, which is an early-sowing culture, depends on the temperature regime of the soil is of particular interest.

How initial development depends on environmental conditions is little reported in literary sources. To a greater extent, there is detailed information on the formation of elements of ear productivity as a result of the influence of the external environment, where it is stated that among the factors to which plants respond sensitively are the duration of the light period of the day and temperature.

In the description of macrophenological phases, it is noted that the zero phase is the seedling phase, when a coleoptile appears on the soil surface. How factors of the external environment affect germination is little reported in literary sources and we do not find detailed information. However, it is the phase of seed germination that is quite important, it is the field germination, the dynamics of seedling emergence, and the balanced growth and development of plants that depend on it. The relevance of the research lies in the fact that, according to its biological characteristics, barley belongs to the crops of the early sowing period, which is often emphasized in literary sources. Scientists pay attention to global climate changes due to warming, which cause an increase in such phenomena as heat, drought, etc. (Niţu et al., 2023). Limiting negative climate change requires technological solutions and new approaches. In particular, this applies not only to barley, but also to such an important grain crop as wheat (Partal et al., 2023; Lozinskiy et al., 2023). It is possible to resist these changes, in particular regarding the cultivation of spring barley in Ukraine, thanks to the observance of early sowing dates. How to use this feature for practical purposes? The task of scientific research takes an important position, in particular, how favorable is the ecosystem in accordance with the culture of spring barley during the early sowing period regarding the issue of the phase of seed germination before the emergence of seedlings. Undoubtedly, the perfection and development of technologies consists in the effective use of agrotechnical resources of the external environment – vegetation factors in relation to the development of plants and the realization of the biopotential of agrophytocenosis. In general, the agroecosystem is created by a certain part of the technology, the task of which is to effectively use the accumulated energy of sunlight, which accumulates in the soil from the very beginning of the spring warming. This is the ecological expediency of the development of crop production, both the maximum and the full rational use of the energy resource of the environment.

The purpose of the research is to improve the existing technology for growing malting spring barley developed over the past decade in cooperation with the National Academy of Sciences of Ukraine.

MATERIALS AND METHODS

The organization of the field experiment took place by laying out plots in 4 repetitions with a registered area of 20 m^2. Sowing dates: the first – March 10, the second – March 20, the third – March 30, the fourth – April 9, the fifth – April 19. The object of research is the Sebastian spring barley plant. The seeding rate is 250 sprouting seeds/m^2.

The soil temperature was determined according to the Pessl Instruments iMetos IMT300USW weather station.

The research was carried out during 2015-2017 at the Higher Educational Institution "Podillia State University" in the conditions of the Western Forest Steppe of Ukraine.

Agrochemical characteristics of the soil of experimental plots. The type of soil is chernozem, gilded with medium loam, characterized by its physical and agrochemical properties as favorable for growing agricultural crops. Humus content is 3.2%, supply of nutrients: alkaline hydrolyzed nitrogen – 100 mg per 1 kg of soil, mobile phosphorus P_2O_5 – 176 mg per 1 kg of soil, exchangeable potassium K_2O – 160 mg per 1 kg of soil. The reaction of the soil solution is close to neutral or neutral – the pH of the salt extract is 6.8-7.0 mg-eq./100 g of soil, the hydrolytic acidity is low 0.56-0.62 mg-eq./100 g of soil, the amount of absorbed bases 32-36 mg-eq./100 g of soil.

The content of humus was determined according to the Tiurin method, alkaline hydrolyzed nitrogen – according to the Kornfield method, mobile phosphorus and exchangeable potassium – according to the Chirikov method, the amount of absorbed bases – according to the Kappen-Hilkovits method, the reaction of the soil pH solution with salt – according to the potentiometric method, hydrolytic acidity – according to the Kappen method.

The experiment was organized under the condition of forming crops with a rowing space of 15 cm – the usual row method of sowing. The depth of seed wrapping is within 2-3 cm. The parameters of the grain weight of the barley seeds used for sowing are 48-52 mg.

Correlation-regression analysis was used for the mathematical analysis of the obtained research results in order to establish the dependence of the sowing-seedling period on the temperature conditions of the environment.

RESULTS AND DISCUSSIONS

Growing spring barley is ensured by agrometeorological conditions, where agroclimatic resources determine the start and end of the growing season (Lipinskii et al., 2003).

Accordingly, agricultural resources depend on the intensity of heat accumulation and the amount of precipitation for certain periods. The total heat demand of barley is determined by the total number of positive temperatures during the growing season. The idea of R.A. Reomura explains the irreversible processes of biological reactions that ensure growth and development with appropriate sums of temperatures for all periods of phenotype formation (Lipinskii et al., 2003).

The potential of agroclimatic resources in terms of volume for spring barley depends on the degree of their favorability, which causes, as a rule, different levels of productivity.

According to the record of soil temperature in the last decade, the degree of favorability for barley sowing is ensured already in the months of February and March. In particular, the heat demand in the pre-sowing period in 2015 was ensured at the level of 2.4°C for the period from February 25 to March 10 (average value of the indicator). In 2016, the favorable pre-sowing period lasted 26 days from February 14 to March 10, with an average soil temperature of 3.5°C. In 2017, the pre-sowing period of positive soil temperatures was 8 days. However, the temperature regime of the soil was quite favorable. The average value of the indicator for this period was 3.6°C.

The conducted research with barley culture in relation to sowing dates in the period from 2015-2017 makes it possible to establish the dependence of the duration of seedlings or the intensification of development in the process of germination from the influence of environmental factors. The peculiarity of this phase of development, as an exception compared to all others, is that the development of the embryonic root and shoot does not depend on the supply of carbohydrates synthesized by the leaf apparatus, it is not yet there. Clearly, the root system begins to function in barley much earlier than the photosynthesis of the first truly developed leaf begins.

In foreign literary sources, it is noted that the growth and development of the above-ground part of plants depends on the intensity of the functioning of the root system, and the growth of the root system, in turn, depends on the above-ground part of plants. During the phase of seed germination, such a relationship is excluded.

According to the obtained data, the intensity of growth processes, namely the germination of barley, depends on the temperature regime of the soil. In 2015, when barley was sown on March 10, germination took 17 days with the average soil temperature during this period of 3.46°C. The temperature regime of the soil during this period is characterized by the coefficient of variation V – 26.7% with minimum values of 2.5°C and maximum values of 6.1°C. Air temperature indicators for the same period are characterized by the coefficient of variation V – 56.8% with an average daily temperature parameter of 4.1°C. The maximum temperature during this period was 9.4°C, and the minimum was 0.2°C. Plant bushing began on April 12 (Table 1).

Under the condition of sowing on March 20, germination occurred for 16 days at an average soil temperature of 4.51°C, where the coefficient of variation of the data was V – 31.4%, at a maximum temperature of 6.6°C and a minimum of 2.6°C. During the same period, the variation of these air temperatures was at the level of V – 54.0%, according to the average air temperature of 5.0°C, where the maximum values were 9.4°C and the minimum 0.2°C. The planting of plants on the condition of sowing on March 20 began on April 18.

When sowing after 10 days on March 30, the duration of germination or germination phase was also 16 days at average values of the soil temperature index for this period of 5.09°C, where the coefficient of variation of soil temperature was V – 32.5%, with a value of maximum data of 8.2°C and minimum 3.0°C. The index of data variation for the same period in relation to air temperature was V – 60.4% with an average daily temperature of 6.0°C, and the maximum air temperature was 12.8°C, and the minimum 1.3°C. Bushing of barley plants during this sowing period started on April 27.

Sowing on April 9 took place under the best conditions of the soil temperature regime. Seedlings appeared 14 days after sowing, the average value of the soil temperature was 6.75°C, with the established variation of the V data – 18.7%, the maximum temperature values were at the level of 8.8°C, and the minimum 4.9°C. During the same period, the temperature regime of the air is characterized by the coefficient of variation V – 40.9%, with maximum values of 14.7°C and minimum values of 4.0°C, with an average daily air temperature of 8.3°C. Bushing of plants for sowing on April 9 began on May 4.

Table 1. The development of barley plants during the period of sowing – seedling depending on the temperature regime of the soil

Sowing period	Duration, days	Air temperature, °C					Soil temperature, °C				
		amount	average	V, %	max.	min.	amount	average	V, %	max.	min.
2015											
10.03	17	70.4	4.14	56.8	9.4	0.2	58.9	3.46	26.7	6.1	2.5
20.03	16	80.1	5.01	54.0	9.4	0.2	72.2	4.51	31.4	6.6	2.6
30.03	16	96.5	6.03	60.4	12.8	1.3	81.5	5.09	32.5	8.2	3.0
09.04	14	115.6	8.26	40.9	14.7	4.0	94.5	6.75	18.7	8.8	4.9
19.04	12	130.7	10.90	48.8	17.4	4.0	102.1	8.51	27.1	11.6	5.5
2016											
10.03	17	50.0	2.94	70.6	8.1	-0.6	61.7	3.63	30.7	6.5	2.0
20.03	15	75.8	5.06	73.1	12.8	0.4	69.8	4.65	45.6	9.0	2.0
30.03	11	138.0	12.54	35.0	17.2	4.5	101.8	9.25	27.0	12.5	6.3
09.04	9	126.6	14.07	15.1	17.4	10.4	108.2	12.02	4.8	12.6	10.7
19.04	11	101.5	9.23	27.3	12.9	4.9	102.4	9.31	11.9	11.6	7.7
2017											
10.03	17	80.9	4.76	55.3	12.3	1.4	75.0	4.41	29.3	7.1	2.8
20.03	14	119.0	8.50	45.2	15.4	2.5	87.6	6.26	26.4	9.2	3.0
30.03	11	115.0	10.46	36.9	15.4	5.5	93.2	8.47	15.6	10.3	6.8
09.04	13	88.5	6.80	24.9	10.0	4.0	87.9	6.76	13.2	8.1	5.2
19.04	12	110.6	9.22	54.5	17.6	3.5	89.4	7.45	29.6	11.2	5.2

And the sowing carried out on 19.04 was better characterized by the intensity of the germination phase, the average value of the soil temperature was 8.51°C, and the duration of barley germination was 12 days. At the same time, the coefficient of variation of the soil temperature indicators was V – 27.1% with maximum values of temperature data of 11.6°C and minimum values of 5.5°C. For air temperature indicators for the same period, the coefficient of variation was at the level of V – 48.8% with the established average daily air temperature indicator of 10.9°C based on the data of maximum indicators of 17.4°C and minimum of 4.0°C. Bushing of plants began on May 11.

In 2016, the regularity of the duration of the germination phase due to the influence of the temperature regime of the soil is repeated. Under the condition of sowing on March 10, the duration of this phenophase was 17 days. During this period, the average value of the soil temperature index was set at 3.63°C, with a variation of V data of 30.7%, where the maximum values of the temperature index were 6.5°C, and the minimum values were 2.0°C. During the same period, the average value of air temperature data for 17 days was at the level of 2.94°C with a variation of V data of 70.6% with a range of indicators from a minimum value of -0.6°C to a maximum of 8.1°C. Bushing of plants under the condition of sowing on March 10 began on April 10.

When sowing on March 20, the duration of barley germination was 2 days shorter – 15 days, the average daily soil temperature was 4.65°C with the set coefficient V – 45.6%, where the maximum temperature was 9.0°C and the minimum was 2.0°C. During the same period, the average daily value of the air temperature was 5.06°C, with the coefficient of variation V – 73.1%. Fluctuations in air temperature ranged from a minimum value of 0.4°C to a maximum value of 12.8°C. Bushing of plants began on April 15.

Under the condition of sowing on March 30, seedlings appeared on the 11th day at an average daily value of the soil temperature during this period of 9.25°C, where the coefficient of variation was V – 27.0% with temperature fluctuations from 4.5°C to 17.2°C. During the same period, the average air temperature was at the level of 12.5°C with the corresponding coefficient of variation of the data V – 35.0% with minimum values of 4.5°C and maximum values of 17.2°C. Bushing of barley plants during this sowing period began on April 23.

When sowing 10 days later, that is, on April 9, germination took place for 9 days. The corresponding average daily soil temperature for this period was 12.0°C with the established coefficient of variation of the data V – 4.8%, where the minimum temperature values were 10.7°C, and the maximum 12.6°C. During the same period, the average air temperature was 14.1°C, with a coefficient of variation V of 15.1%, with a minimum temperature of 10.4°C and a maximum of 17.4°C. Bushing of plants, provided that sowing was done on April 9, began on May 2.

Under the conditions of sowing on April 19, the temperature regime of the soil was somewhat similar to that of crops sown on March 30. Accordingly, the duration of germination was also 11 days for the average daily value of the soil temperature for this period of 9.3°C, the coefficient of variation was V – 11.9% for the established temperature indicators of minimum values of 7.7°C and maximum values of 11.6°C. The average air temperature during this period was at the level of 9.2°C with a variation of V data of 27.3%, where the maximum values were at the level of 12.9°C, with minimum values of 4.9°C. Weeding of plants began on May 11.

The conditions of 2017 in terms of the temperature regime of the soil were similar to the conditions of 2015 and 2016 in comparison of individual sowing dates. The duration of barley germination of crops of the first sowing period was 17 days, where the average value of the soil temperature indicator was 4.4°C with the established coefficient of variation V – 29.3%, where the maximum soil temperature indicators during this period were 7.1°C, and minimum 2.8°C. During the same period, the average value of the air temperature indicator was 4.8°C with a variation of V data of 55.3% with temperature fluctuations from the minimum values of 1.4°C to the maximum of 12.3°C. Bushing of plants under the condition of sowing on March 10 began on April 10.

When sowing on March 20, the duration of the sowing-emergence period was less than 14 days. The average daily value of the soil temperature was slightly higher, the indicator was 6.26°C, with the established coefficient of variation V – 26.4% with maximum temperature values of 9.2°C and minimum 3.0°C. During the same period, the average daily value of the air temperature was at the level of 8.5°C according to the variation of V data – 45.2% with fluctuations in values from a minimum of 2.5°C to a maximum of 15.4°C. Bushing of plants began on April 17.

When sowing on March 30, the temperature conditions were slightly better. The duration of germination decreased to 11 days. The average daily value of the soil temperature during this period is characterized by an increase in heat, and according to these conditions, the duration of the germination phenophase decreased by 3 days compared to the previous sowing period. The average daily temperature index of the soil during this period was 8.5°C with a variation of V data of 15.6%, where the minimum soil temperature values were 6.8°C and the maximum 10.3°C. During the same period, the average value of the air temperature indicator was 10.5°C, with a variation of V data of 36.9%, where the minimum indicator was at the level of 5.5°C, and the maximum was 15.4°C. Bushing of barley plants during this sowing period began on April 26.

During the next sowing period on April 9, the duration of the sowing-seedling period, or the germination phase, increased to 13 days, as there was a cooling. On average, the soil temperature for this period was 6.76°C, with a variation of V data of 13.2%, where the minimum value was 5.2°C, and the maximum was 8.1°C. The average daily air temperature for this period was 6.8°C with a variation of V data of 24.9% for the set minimum air temperature of 4.0°C and maximum of 10.0°C. Bushing of plants began on May 7.

At the next term of sowing, i.e. on April 19, despite some improvement in soil temperature, germination lasted 12 days with an average daily parameter during this period of 7.45°C, the variation component of the temperature data was at the level of V – 29.6% with minimum values of 5.2°C and maximum data of 11.2°C. The temperature regime of the air during this period is characterized by an average daily indicator of 9.2°C with a variation of V data of 54.5% for the set minimum indicators of 3.5°C and maximum of 17.6°C. Bushing of plants, provided that sowing was done on April 19, began on May 11.

The conducted correlation analysis of the dependence of soil temperature data on air temperature during the period of duration of the germination phase of spring barley shows a strong relationship, which is r=0.96. Also, a strong correlation between the sum of soil temperature indicators during the period of spring barley germination and the sum of air temperature during this period was established, where r=0.90.

So, the sowing of barley for five terms, starting from March 10 to April 19 after 10 days inclusive, made it possible to establish that the duration of the germination phenophase is influenced by the temperature of the soil, which was the only exception in this study, since the light regime of the day is excluded here. Therefore, it is the vegetation factor, in particular the heat supply of the soil, that plays an important role, which, without a doubt, cannot be controlled anthropogenically. The relationship between the intensity of the barley germination process and the parameters of the number of days from sowing to the emergence of seedlings is a dependent indicator of the temperature regime of the soil, which is characterized by the correlation coefficient R=-0.97. The established regression equation dpS-S *(duration of the period of sowing – seedling)* = 20.56175 – 1.02881 × Ts *(temperature of the soil)* (F_f>F_t, p=0.00) makes it possible to predict the duration of the germination process from the influence of the soil temperature regime. In particular, an increase in the average daily value of the soil temperature by 1°C during the corresponding period of seed germination will contribute to reducing the duration of this period by 1 day.

In the characteristics of heat requirements, it should be noted that barley is undemanding and begins to germinate at a temperature of 1-2°C (Ko et al., 2019). The biological minimum temperature for barley from the beginning of growth is 5.0°C (Polupan et al., 2019), which is already included in the parameters of the favorability degree. At a temperature of 4°C, germination of barley seeds occurs in 5-6 days, at 10°C in 3 days. How the growth and development of spring barley occurs during the early sowing period, in particular before the onset of generative development in the conditions of the Western Forest Steppe of Ukraine due to global climate changes, it has not been investigated and it has not been fully clarified how much it positively or negatively affects plant productivity and grain yield, it requires detailed study and analysis of research results.

CONCLUSIONS

The regularity of the decrease in the duration of the germination phase of spring barley in the conditions of the Western Forest Steppe with the postponement of the sowing dates in accordance with the dates 10.03; 20.03; 30.03; 09.04; 19.04 was established.

Barley germination took place depending on the conditions of the year during the first sowing period for 17 days, during the second – 14, 15, 16 days, during the third – 11, 11, 16, during the fourth – 9, 13, 14 days, during the fifth – 11, 12, 12 days.

A decrease in the duration of the germination phase of spring barley takes place under the condition of an increase in soil temperature, the corresponding correlation coefficient r = -0.97 is established.

In the characteristics of the barley germination period, a direct correlation between the soil temperature regime and the air temperature is established, where the correlation index is r=0.96.

The dependence of the onset of the tillering phase in spring barley plants on the sowing dates was revealed, where in the first tillering period it began on April 10-12, in the second – on April 15-18, in the third – on April 23-27, in the fourth – on May 2-7, for the fifth – May 11.

REFERENCES

Basu, S., Ramegowda, V., Kumar, A., Pereira, A. (2016). Plant Adaptation to Drought Stress. *F1000Research, 5 (1554)*: 1-10. https://doi.org/10.12688/f1000research.7678.1.

Bomba, M., Dudar, I., Lytvyn, O., Potopliak, O. (2020). Formuvannja vrozhaju sortiv jachmenju jarogo zalezhno vid normy vysivu [Yield formation of spring barley varieties depending on the seeding rate]. *Bulletin of the Lviv National Agrarian University: Agronomy, 24,* 67–71. https://doi.org/10.31734/agronomy2020.01.067. (in Ukrainian).

Bondar, O., Melnyk, Ye., Tsytsiura, N., Dukh, O., Halahan, I. (2023). Analysis of the structure and fertility of agricultural land in western Ukraine and its monetary assessment. *Scientific Horizons, 26*(5), 108-122. https://doi.org/10.48077/scihor5.2023.108.

Buturlym, D. A., Bondar, I. M. (2021). Vymogy do zerna jarogo pyvovarnogo jachmenju, tehnologija pisljazbyral'noi' pererobky ta zberigannja [Requirements for spring malting barley grain, post-harvest processing and storage technology]. *The latest technologies in scientific activity and the educational process, 18-19 March 2021,* 296-298 (in Ukrainian).

Christidis, N., Stott, P. A. (2021). The influence of anthropogenic climate change on wet and dry summers in Europe. *Science Bulletin, 66*(8), 813-823. https://doi.org/10.1016/j.scib.2021.01.020.

Cojocaru, O. (2020). Potential impact of climate change on agroecosystems in the Republic of Moldova. *AgroLife Scientific Journal, 9*(1), 96-103.

Dehtiarov, Y. (2023). Formation of soil structure of chernozems in different agroecosystems. *Scientific Papers. Series A. Agronomy, LXVI*(1), 48-53.

Dudar, I., Lytvyn, O., Pavkovych, S., Korpita, H., Kozliuk, O. (2022). Yield of winter barley depending on mineral nutrition. *Journal of Lviv National Agrarian University: agronomy, 26,* 72–76. https://doi.org/10.31734/agronomy2022.26.072 (in Ukrainian).

Gavriliuk, M. M. (2009). Suchasni zavdannja agrarnoi' nauky v rozvytku genetyky, selekcii' ta nasinnyctva [Modern tasks of agricultural science in the development of genetics, breeding and seed production]. *Bulletin of Agricultural Science, 1,* 5-10 (in Ukrainian).

Gorobets, M. V., Pisarenko, P. V., Chaika, T. O., Mishchenko, O. V. (2020). Naukovi pidhody shhodo ekologizacii' tehnologii' vyroshhuvannja jachmenju jarogo v umovah Livoberezhnogo Lisostepu [Scientific approaches to greening the spring barley growing technology in the conditions of the Left Bank Forest Steppe]. *Bulletin of Poltava SAA, 4,* 142–149. https://doi.org/10.31210/visnyk2020.04.17 (in Ukrainian).

Horash, O. S. (2017). Upravlinnja producijnym procesom pyvovarnogo jachmenju: Monografija. 2 vydannja z dopovnennjamy [Management of the production process of malting barley: Monograph. 2 editions with additions]. Kamianets-Podilskyi: PP "Medobory-2006", 464 (in Ukrainian).

Horash, O. S., Klymyshena, R. I. (2019). Jachmin': Teoretychni osnovy tehnologii' vyroshhuvannja. Navchal'no-praktychne vydannja [Barley: Theoretical foundations of cultivation technology. Educational and practical edition]. Kamianets-Podilskyi, 64 (in Ukrainian).

Horash, O. S., Klymyshena, R. I. (2020). Jachmin': upravlinnja pyvovarnoju jakistju: Monografija [Barley: brewery quality management: Monograph]. Kamianets-Podilskyi: "Drukarnia Ruta" LLC, 260 (in Ukrainian).

Hospodarenko, H. M., Stasinevych, O. Yu., Prokopenko, E. V. (2015). Vrozhajnist' zerna jachmenju jarogo za tryvalogo zastosuvannja dobryv u pol'ovij sivozmini [Yield of spring barley grain under long-term use of fertilizers in field crop rotation]. *Bulletin of the Uman National University of Horticulture, 1,* 3-6 (in Ukrainian).

Ishchenko, V. A. (2021). Vplyv zastosuvannja reguljatoriv rostu na urozhajnist' ta formuvannja elementiv produktyvnosti roslyn jachmenju jarogo v umovah stepovoi' zony Ukrai'ny [The influence of the use of growth regulators on the productivity and formation of elements of productivity of spring barley plants in the conditions of the steppe zone of Ukraine]. *Bulletin of Poltava SAA, 2,* 81–85. https://doi.org/10.31210/visnyk2021.02.10 (in Ukrainian).

Kasatkina, T. O., Gamaiunova, V. V. (2018). Perspektyvy ta osoblyvosti vyroshhuvannja jachmenju jarogo na pivdni Ukrai'ny [Prospects and features of growing spring barley in the south of Ukraine]. *Scientific horizons, 7-8*(70), 131–138 (in Ukrainian).

Kim, Y.-G., Park, H.-H., Lee, H.-J., Kim, H.-K., Kuk, Y.-I. (2022). Growth, Yield, and Grain Quality of

Barley (*Hordeum vulgare* L.) Grown across South Korean Farmlands with Different Temperature Distributions. *Agronomy, 12*, 2731. https://doi.org/10.3390/agronomy12112731.

Ko, J., Ng, C. T., Jeong, S., Kim, J. H., Lee, B., Kim, H. Y. (2019). Impacts of regional climate change on barley yield and its geographical variation in South Korea. *Int. Agrophys, 33,* 81–96. https://doi.org/10.31545/intagr/104398.

Kononyuk, V. A., Borysonik, Z. B., Musatov, A. G. etc. (1986). Jachmin' [Barley]. K.: Urozhaj, 6-7. (in Ukrainian).

Kosová, K., Prášil, I. T., Vítámvás, P. (2013). Protein contribution to plant salinity response and tolerance acquisition. *International Journal of Molecular Sciences, 14,* 6757–6789. https://doi.org/10.3390/ijms14046757.

Kosova, K., Vitamvas, P., Prasil I. T. (2014). Proteomics of Stress Responses in Wheat and Barley – Search for Potential Protein Markers of Stress Tolerance. *Frontiers in Plant Science, 5:711.* https://doi.org/10.3389/fpls.2014.00711.

Kostadinova, S. (2023). Content of macronutrients of malting barley in dependence of nitrogen nutrition level. *Scientific Papers. Series A. Agronomy,* LXVI(1), 110-115.

Lamaoui, M., Jemo, M., Datla, R., Bekkaoui, F. (2018). Heat and Drought Stresses in Crops and Approaches for Their Mitigation. *Frontiers in Chemistry, 6*(26): 1-14. https://doi.org/10.3389/fchem.2018.00026.

Lipinskii, V. M., Dyachuk, V. A., Babichenko, V. M. (2003). Klimat Ukrai'ny [Climate of Ukraine]. K.: Ed. Raevsky, 343 (in Ukrainian).

Lozinskiy, M., Burdenyuk-Tarasevych, L., Grabovskyi, M., Grabovska, T., Roubík, H. (2023). Winter wheat (T. aestivum L.) yield depending on the duration of autumn vegetation and the terms of spring vegetation recovery: 50-years study in Ukraine. *Scientific Papers. Series A. Agronomy, LXVI*(1), 406-415.

Mittler, R. (2006). Abiotic stress, the field environment and stress combination. *Trends in Plant Science, 11,* 15–19. https://doi.org/10.1016/j.tplants.2005.11.002.

Niţu, O. A., Ivan, E. Ş., Niţu, D. S. (2023). Climate change and its impact on water consumption in the main agricultural crops of the Romanian Plain and Dobrogea. *Scientific Papers. Series A. Agronomy, LXVI*(1), 474-478.

Partal, E., Oltenacu, C. V., Paraschivu, M., Cotuna, O., Contescu, E. L. (2023). Wheat yield and quality under the influence of sowing date, plant density and variety in South of Romania. *Scientific Papers. Series A. Agronomy, LXVI*(2), 339-345.

Petrychenko, V. F., Korniichuk, O. V. (2018). Strategii' innovacijnogo rozvytku kormovyrobnyctva Ukrai'ny v umovah suchasnyh vyklykiv [Strategies of innovative development of fodder production of Ukraine in the conditions of modern challenges]. *Bulletin of Agricultural Science, 1*(778), 11–17. https://doi.org/10.31073/agrovisnyk201801-02 (in Ukrainian).

Polupan, M. I., Solovei, V. B., Velychko, V. A. etc. (2005). Specializacija zemlerobstva – strategichna osnova pidvyshhennja efektyvnosti i stalogo rozvytku APK [Agricultural specialization is a strategic basis for improving the efficie*3*ncy and sustainable development of the agricultural sector]. *Bulletin of Agricultural Science, 5,* 11-13 (in Ukrainian).

Polupan, M. I., Velychko, V. A. (2019). Ukrai'ns'ke agronomichne g'runtoznavstvo: pidruchnyk. U 2-h chastynah; za red. M.I. Polupana. Chastyna 1: Istorychni etapy rozvytku. Faktory g'runtoutvorennja. Zakonomirnosti formuvannja g'runtiv na ekologo-genetychnij parametrychno systemnij osnovi, i'hnih agronomichnyh vlastyvostej i rodjuchosti [Ukrainian agronomic soil science: textbook. In 2 parts; under the editorship M.I. Polupan. Part 1: Historical stages of development. Factors of soil formation. Patterns of soil formation on an ecological-genetic parametric system basis, their agronomic properties and fertility]. Kyiv: Agrarian Science, 426 (in Ukrainian).

Polupan, M. I., Velychko, V. A. (2019). Ukrai'ns'ke agronomichne g'runtoznavstvo: pidruchnyk. U 2-h chastynah; za red. M.I. Polupana. Chastyna 2: Klasyfikacija g'runtiv. G'runtovo-ekologichne rajonuvannja. Zonal'nist' jak faktor geografii' g'runtiv za ekologo-genetychnym statusom, i'hni morfologichna i kil'kisna diagnostyky, agrog'runtovyj potencial sil's'kogospodars'kyh kul'tur. Specializacija zemlerobstva vidpovidno do g'runtovo-ekologichnyh umov. Monitoryng zemel'nyh resursiv. Doktryna racional'nogo zemlekorystuvannja v Ukrai'ni [Ukrainian agronomic soil science: textbook. In 2 parts; under the editorship M.I. Polupan. Part 2: Classification of soils. Soil and ecological zoning. Zoning as a factor of soil geography according to ecological and genetic status, their morphological and quantitative diagnostics, agro-soil potential of agricultural crops. Specialization of agriculture according to soil and ecological conditions. Monitoring of land resources. The doctrine of rational land use in Ukraine]. Kyiv: Agrarian Science, 444 (in Ukrainian).

Puzik, L. M. (2019). Pyvovarni vlastyvosti zerna jachmenju jarogo za riznyh umov zberigannja [Brewing properties of spring barley grain under different storage conditions]. *Bulletin of Kharkiv National Technical University of Agriculture, 207,* 148-153 (in Ukrainian).

Radishchuk, T. P. (2015). Vplyv kon'junktury tovarnogo rynku na innovacijnyj rozvytok pidpryjemstva [The influence of the commodity market situation on the innovative development of the enterprise]. *Agroworld*, *20,* 98–104 (in Ukrainian).

Rybalka, O. I., Morgun, B. V., Polishchuk, S. S. (2016). Jachmin' jak produkt funkcional'nogo harchuvannja: monografija [Barley as a product of functional nutrition: monograph]; chief ed. V.V. Blinker. K.: Logos, 619 (in Ukrainian).

Shuvar, I., Korpita, H., Dudar, O. (2021). Formation of the spring barley yield depending on climate conditions of the Western Forest-Steppe of Ukraine. *Journal of Lviv National Agrarian University: agronomy, 25,* 60–62. https://doi.org/10.31734/agronomy2021.01.060 (in Ukrainian).

Tkachuk, V., Tymoshchuk, T., Hrytsiuk, N., Kotelnytska, G. (2018). Vplyv strokiv sivby i norm vysivu na zabur'janenist' i produktyvnist' agrofitocenozu jachmenju ozymogo [Influence of sowing dates and seeding rates on weediness and productivity of agrophytocenosis of winter barley]. *Bulletin of the Lviv National Agrarian University: Agronomy, 22*(2), 29-33. https://doi.org/10.31734/agronomy2018.02.029 (in Ukrainian).

Toma, A. I., Dobrinoiu, R. V., Gîdea, M. (2024). Influence of the technological practices optimization on the yield components at two-row barley for beer in the Nord-Western conditions of the Romanian Plain. *Scientific Papers. Series A. Agronomy, LXVII*(1), 725-733.

Vozniuk, N., Skyba, V., Likho, O., Sobko, Z., Klymenko, T. (2023). Forecasting the adaptability of heat-loving crops to climate change in Ukraine. *Scientific Horizons, 26*(2), 87-102. https://doi.org/10.48077/scihor.26(2).2023.87-102.

Yang, F., Melo-Braga, M. N., Larsen, M. R., Jørgensen, H. J. L., Palmisano, G. (2013). Battle through signaling between wheat and the fungal pathogen *Septoria tritici* revealed by proteomics and phosphoproteomics. *Molecular & Cellular Proteomics, 12,* 2497–2508. https://doi.org/10.1074/mcp.M113.027532.

Yatsyuk, M., Adamenko, T., Romaschenko, M., Tsvetkova, G., Kolmaz, Yu., Kulbida, M., Prokopenko, A., Saidak, R., Sydorenko, O. (2021). Conceptual foundations of the drought management plan in Ukraine. Kyiv. Retrieved from https://dspace.organic-platform.org/xmlui/handle/data/424?locale-attribute=uk (in Ukrainian).