Scientific Papers Series Management, Economic Engineering in Agriculture and Rural Development
Vol. 22, Issue 4, 2022
PRINT ISSN 2284-7995, E-ISSN 2285-3952

FORMATION OF PHYTOCENOSIS OF WINTER BARLEY (*HORDEUM VULGARE L.*) DEPENDING ON HYDROTHERMAL CONDITIONS OF THE AUTUMN PERIOD AND AGRICULTURAL TECHNOLOGICAL MEASURES

Raisa VOZHEHOVA, Serhii ZAIETS, Oleksandr RUDIK, Vira BOROVYK, Stanislav HOLOBORODKO, Tetiana MARCHENKO, Serhii YUZIUK, Liudmyla ONUFRAN, Kateryna FUNDYRAT, Liubov BOIARKINA

Institute of climate smart agriculture of the NAAS, 24, Mayatska doroga Street, sett. Khlybodarske, Bilyaivsky district, Odesa region, Ukraine, 67667; E-mailS: icsanaas@ukr.net, szaiets58@gmail.com, oleksandr.rudik@gmail.com, veraborovik@meta.ua, goloborodko1939@gmail.com, tmarchenko74@ukr.net, ludmilaonufran@gmail.com, kfundirat@gmail.com, boyarkina.08@ukr.net

Corresponding author: veraborovik@meta.ua

Abstract

This article presents the results of research on the formation of phytocenosis of winter barley (Hordeum vulgare L.) depending on the hydrothermal conditions of the autumn period, varietal characteristics and sowing dates in irrigated lands in the South of Ukraine. Based on long-term research on irrigated lands on the growth and development of plants in the autumn growing season and increasing winter hardiness of winter barley varieties, it has been established that irrigation efficiency has significantly increased over the past twenty years due to regional climate change. Moreover, the extended period of autumn vegetation requires a change in the timing of sowing of winter crops on 13-15 days later. Domestic breeders have created new varieties of winter wheat and winter barley with a short period of vernalization, which are less responsive to the reduction of daylight hours, and some of them have increased winter hardiness.On average, in 1998-2001, the shift in the sowing date of winter barley from September 20 to October 15 led to a deterioration of growth processes, and during the last sowing period, tillering did not occur in the autumn. Among the biomorphological indicators of barley plants there is a close correlation between bushiness, ground mass of plants and their height (r = 0.94-0.99). Compared to the period 1971-1990, the sum of average daily air temperatures in 2001-2005 increased by 110°C, in 2006-2010 – by 191°C, in 2011-2015 – by 222°C and in 2016-2020 – 220°C, and the autumn growing season increased by 8, 10, 15 and 13 days, respectively. On the other hand, the amount of precipitation in most cases was less than the long-term average. During the sowing of winter barley on September 20, the varieties of the winter barley Akademichnyi, Deviatyi val and Dostoinyi have time to carry out tillering well in autumn, forming 3.5–5.2 shoots. During the sowing on October 1, their bushiness was 2.3–3.2, and during the sowing on October 20, the plants do not have time to carry out tillering well, they enter the winter in the phase of 2-3 leaves. For high hardening of winter barley plants and accumulation of sugars in bushes at the level of 30.22-38.8%, the best time for sowing of the studied varieties is the beginning of October.

***Key words*:** *formation of phytocenosis, sowing date, bushiness, irrigated lands, winter hardiness, prolongation of the autumn vegetation period*

INTRODUCTION

The instability of food grain production observed in the steppe zone in recent years is largely due to regional and global climate change [10, 11]. Statistical analysis of long-term indicators of air temperature shows a steady tendency to increase the average annual air temperature with significant fluctuations of indices in some periods from 7.9 ± 2.9 to 10.0 ± 2.5°C and reduce the amount and instability of natural moisture [17]. On the basis of correlation-regression analysis, mathematical models have been created that reproduce the dependence of grain yield on difficult weather conditions of the growing season, the impact of which reaches 60-70% [13].

It should be recognized that temperature is one of the most important uncontrolled limiting factors of the environment. According to the Intergovernmental Panel on Climate Change (IPCC), in the next 100 years the temperature on the planet will rise by 4-6°C [19], winters will be shorter and warmer, springs will be colder, summer will be hotter [3].

Similar phenomena have been observed in the last four decades in the Orenburg region, where the climate has changed towards a significant increase in average annual air temperature from 4.5°C to 6.2°C and a decrease in annual rainfall – from 380 to 320 mm. For winter and early cereals, these changes led to a sharp decrease in crop yields by about 2 times compared to the maximum in the 90s [8, 18]. Such climatic challenges will lead to even greater aridity of the Southern Steppe of Ukraine. Therefore, in this area only irrigation can ensure sustainable production and high yields of crops [23, 24].

The foundations of the productive potential of winter cereals are laid at the initial stage of plant growth [21]. Therefore, special attention in the cultivation of winter barley should be paid to the autumn growing season, where the key issue is to establish the optimal sowing period.

Global climate change affects some abiotic factors (such as temperature and precipitation). Therefore, adapted varieties to a particular region may react negatively to changing climatic conditions, as they cause inconsistencies in plant phenology [4]. At present, many ecological zones are already showing clear signs of agro-climatic deterioration due to increased drought, leading to a reduction in the active growing season, which in some regions is between cold winters and hot summers. The results of research show that there is a risk of increasing the number of adverse years in many climatic zones, which can lead to negative changes in yields and make it difficult to grow crops [9, 22]. Climate change has made adjustments to the rather complex and ambiguous issue of sowing dates for winter barley, which is one of the main factors in the technological process, which significantly affects the passage of production processes and crop formation. It is known that plants of different sowing dates grow and develop differently, acquire different resistance to biotic and abiotic factors, resulting in different grain size and quality of grain yield [25].

The question of the optimal sowing date of winter cereals in the steppe zone of Ukraine has been studied by many researchers, who came to the conclusion that the optimal time should be shifted on 10-15 days later, compared to the recommendations, which were given 15-20 years ago [15, 20]. Due to global climate change, a number of scientists in their publications also propose to postpone the allowable sowing of winter crops to a later date [5, 26]. Scientists also say that the timing of sowing will be significantly affected by extreme weather conditions, during which heat amplitudes will be replaced by heavy rainfall. Therefore, for coordinated climate forecasts on a pan-European scale, scientists from Europe and other continents model the climate based on temperature, precipitation and extreme winds in order to use it effectively [1, 6, 7, 12].

The complexity of this issue lies in its systemicity and randomness, as the optimal time depends on the predecessor, hydrothermal conditions of autumn, soil moisture, varietal characteristics, fertilizer background and plant protection system against diseases and pests, and other factors. In irrigated lands, due to the possibility of regulating the moisture supply at the time of sowing, this issue is not sufficiently studied. In addition, the creations of high-yielding varieties of the new generation of classical and alternative types require field research to determine which of them best meet the changed climatic conditions [2, 16].

Especially important are the timing of sowing of winter crops in the steppe zone during irrigation, which provides optimal conditions for seedlings. However, in this area almost half of their area is sown annually in the late stages, which leads to insufficient development of vegetative mass of plants and liquefaction, resulting in a sharp increase in the risk of death of winter barley plants in winter [26]. During irrigation, winter barley is sown in a moist sowing layer of the soil, so the limiting factor in the emergence of seedlings is the average daily air temperature, which has been rising recently. Thus, the study, which aims to determine the optimal timing of sowing of winter barley under irrigation in the South of Ukraine, is relevant.

MATERIALS AND METHODS

The aim of the study was to determine the impact of hydrothermal conditions and sowing dates on the duration of autumn vegetation, bushiness and accumulation of sugars in the tillering nodes of different varieties of winter barley on irrigated lands in southern Ukraine. Field experiments were conducted on the Inhulets irrigated area of the Institute of Irrigated Agriculture of NAAS, in accordance with generally accepted guidelines.

During 1998-2001, six terms of sowing winter barley were studied on irrigated lands after harvesting corn for silage: September 20 and 25 and October 1, 5, 10 and 15. Shallow tillage was used, and pre-sowing irrigation was provided for guaranteed germination. Optimal soil moisture was maintained by vegetative irrigations with a rate of 300-450 m^3/ha. The nutrition system provided the introduction of N_{30} in pre-sowing cultivation and N_{60} in early spring. The variety of barley Rosava was sown at a rate of 5 million grains per hectare.

Studies that took place during 2015–2018 on irrigated lands after soybean harvest studied varieties of barley Akademichnyi, Deviatyi val and Dostoinyi. Four sowing dates were studied: September 20, October 1, 10, and 20. The main tillage was shallow, to a depth of 10-12 cm. N_{45} was applied to pre-sowing cultivation in early spring. In order to obtain friendly seedlings and favorable moisture supply for the growth and development of winter barley plants in the autumn period in 2015, post-sowing irrigation was carried out at a rate of 450 m^3/ha, and in 2017 – pre-sowing (500 m^3/ha) and seed-calling (250 m^3/ha). The sowing rate was recommended for the Southern Steppe zone of Ukraine and amounted to 4.5 million seeds per hectare. In the selected samples of tillering nods, the sugar content was determined according to Bertrand (State Standard of Ukraine, 26176-91) in the laboratory of analytical research of the Institute of Irrigated Agriculture. Observations of meteorological values were recorded at the Kherson agrometeorological station, located at a distance of 200-400 m from the field experiment.

RESULTS AND DISCUSSIONS

The results of research show that the development of winter barley significantly depended on the temperature regime of the autumn period, which is closely related to the timing of sowing.

Thus, the average daily air temperature of five days of the first and second sowing dates was 15.4 and 15.7°C, respectively, the third and fourth – 14.0 and 13.0°C, the fifth and sixth – 12.3 and 10.6°C (Table 1).

Table 1. Average daily air temperature and duration of autumn vegetation of winter barley depending on sowing dates (average for 1998–2000)

Indexes	Sowing period					
	20 IX	25 IX	1 X	5 X	10 X	15 X
Number of days «sowing-seedlings»	9	10	11	15	16	18
Number of days «sowing-cessation of vegetation»	59	54	49	44	39	34
The average daily air temperature for the first five days after sowing, °C	15.4	15.7	14.0	13.0	12.3	10.6
The sum of average daily air temperatures «sowing-cessation of vegetation», °C	577.1	500.9	420.4	350.4	291.6	230.1

Source: [27].

Under the conditions of sowing on September 20 and October 1, seedlings appeared on the 9th and 11th days, and in the case of sowing on October 5 and 15 – on the 15th and 18th days.

Prior to the cessation of vegetation in autumn, barley plants, depending on the sowing period, grew from 59 to 34 days, during which the sum of average daily air temperatures from «sowing to cessation of vegetation» in autumn decreased by two and a half times – from 577.1 to 230.1°C.

Under such different temperature conditions, the growth processes took place differently (Table 2).

Table 2. Biometric indicators of winter barley plants at the end of autumn vegetation at different sowing dates (average for 1998-2000)

Indexes	Sowing period						±	V,%
	20 IX	25 IX	1 X	5 X	10 X	15 X		
Number of plants at the time of cessation of vegetation in autumn, pcs/m^2	480	406	380	410	464	437	429 ±37	8.8
Number of shoots at the time of vegetation termination in autumn, pcs/m^2	1540	1231	901	833	615	438	926 ±392	43.6
General bushiness	3.2	3.1	2.5	2.1	1.4	1.0	2±1	40.3
Aboveground mass of plants, g/m^2	404.8	318.7	214.1	158.4	111.3	74.8	213.7 ±133.1	59.3
Height of plants, cm	18.2	17.5	17.1	15.7	14.6	13.6	16.1 ±1.9	11.1

Source: [27].

The largest number of plants per unit area (480 pieces/m^2) was found in the case of sowing on September 20, as well as in later periods – October 10 and 15, 464 and 437 pieces/m^2, respectively. The latter was due to the better conditions of moisture supply of the soil layer at the time of sowing in the first period, due to pre-sowing irrigation, and in the latter – due to precipitation. At the same time, during the sowing on October 1, due to the loss of moisture of the upper soil layer, the number of plants at the time of vegetation termination was the lowest – 380 pieces/m^2. The number of shoots per unit area, as well as bushiness, starting from sowing on September 20 and ending on October 15, decreased from 1,540 to 438 pieces and from 3.2 to 1.0, respectively. The time factor for the tillering process was decisive. There was a direct dependence of shoot formation on the sowing date – the later the seeds were sown, the less the plants were bushed. At the same time, a decrease in the vegetative mass and height of plants in the late sowing period was also established. Thus, in the case of sowing on September 20 the aboveground weight of plants was 404.8 g, on October 5 – 214.1 g and on October 15 – 74.8 g, and the height of plants reached – 18.2, 17.1 and 13.6 cm, respectively.

The number of days of the interphase period «sowing-cessation of vegetation», which in content is a reflection of sowing dates, has a close correlation with the total bushiness, plant height and their ground weight (r = 0.98-0.99) (Table 3).

Table 3. Matrix of paired correlations of conditions caused by sowing dates and development of winter barley plants in autumn

	Indexes	1	2	3	4	5	6
1	Number of days «sowing-cessation of vegetation»	x	x	x	x	x	x
2	The average daily air temperature for the first five days after sowing, °C	0.97	x	x	x	x	x
3	The sum of average daily air temperatures «sowing-cessation of vegetation», °C	0.998	0.96	x	x	x	x
4	Number of plants at the time of cessation of vegetation in autumn, pcs/m^2	0.14	0.01	0.18	x	x	x
5	General bushiness	0.99	0.98	0.98	0.00	x	x
6	Aboveground mass of plants, g/m^2	0.98	0.93	0.99	0.27	0.95	x
7	Height of plants, cm	0.99	0.97	0.98	0.01	0.99	0.94

Source: [27].

Given that these indicators directly reflect the winter hardiness of plants, this dependence is evidence of the determining importance of sowing dates for crop development and winter hardiness. Among the biomorphological indicators of barley plants there is a close correlation between bushiness, ground mass of plants and their height (r = 0.94-0.99). According to the results of the definition, the constructed polynomial model of the fourth degree with high accuracy r^2 = 0.9947 describes the change in the coefficient of tillering of winter barley over time (Fig. 1).

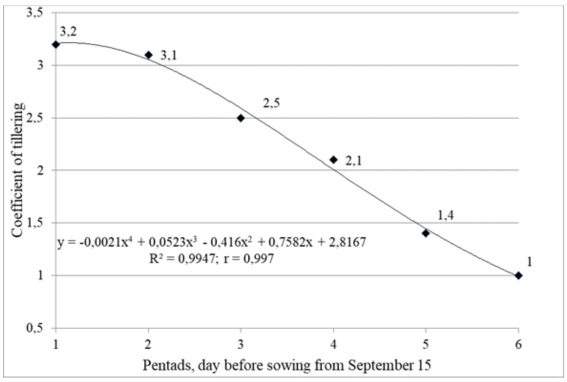

Fig. 1. Polynomial model of change in the value of the coefficient of tillering of winter barley from the time of sowing
Source: [27].

Scientific Papers Series Management, Economic Engineering in Agriculture and Rural Development
Vol. 22, Issue 4, 2022
PRINT ISSN 2284-7995, E-ISSN 2285-3952

The mathematical model has the form:

$$y = -0.0021X^4+0.0523X^3-0.416X^2+0.7582X + 2.8167$$

where:
y-index is a tillering rate at the appropriate sowing date and x- index– pentodes of days from September 15 to the sowing date of winter barley.
The constructed mathematical models with high accuracy allow to predict the development of winter barley crops by the value of the tillering coefficient. On average, in 1998-2000, the shift in the sowing period of winter barley from September 20 to October 15 led to a deterioration of growth processes, and during the last sowing period tillering did not occur in the autumn. It should also be noted that for 20 years of research, since 2001, there has been a marked change in the temperature regime of the autumn growing season of winter barley. Thus, on average for 1971-1990 during the autumn period the sum of average daily air temperatures was 498°C, and in 2001-2005 it reached 608°C, in 2006-2010 – 689°C, in 2011-2015 – 720°C and in 2016-2020 – 718°C, or on 110, 191, 222 and 220°C more, respectively (Table 4).

Table. 4. Changes in temperature and the duration of the autumn growing season of winter barley by years (data of the Kherson Regional Center for Hydrometeorology)

Indexes	Value	Years 1971–1990	2001–2005	2006–2010	2011–2015	2016–2020
Sum of average daily temperatures, °C	factual	498	608	689	720	718
	±	-	+110	+191	+222	+220
Average daily air temperature, °C	factual	8.1	8.6	9.6	+9.9	+9.5
	±	-	+0.5	+1.5	+1.8	+1.4
Duration of autumn vegetation, days	factual	63	71	73	78	76
	±	-	+8	+10	+15	+13

Source: [27].

During these periods, the average daily air temperature also increased by 0.5-1.8°C and the duration of autumn plant vegetation by 8-15 days. That is, there have been significant changes in agrometeorological conditions and noticeable in the direction of warming [26]. Research in 2013-2019 also found that in most cases longer and warmer periods of autumn vegetation of winter cereals were observed. Thus, from July to the third decade of September 2014 and 2018 and mid-October of 2015, 2017 and 2019 in the pre-sowing period of winter barley in the south of Ukraine there were very difficult agrometeorological conditions because of air and soil droughts. Due to such weather conditions, soil moisture for barley sowing was critically insufficient. Vegetative watering of soybean crops, as a predecessor, was completed in the first or third decades of August. Therefore, in order to obtain friendly seedlings and favorable moisture for the growth and development of winter barley plants in the autumn, in 2014 pre-sowing irrigation was carried out at a rate of 500 m^3/ha, in 2015 – post-sowing (450 m^3/ha), and in 2017 – pre-sowing (500 m^3/ha) and seed-calling (250 m^3/ha). In 2013 and 2016, there was no need for pre-sowing irrigation, as in September there was sufficient rainfall to obtain friendly seedlings – 43.7 and 33.2 mm, respectively.
Pre-sowing and seedling irrigation, which were carried out in 2015 and 2017 and rainfall against the background of high temperatures in November, helped to improve the condition of winter barley plants. During October – November, 62.8 and 52.6 mm of precipitation were received, respectively, which was 98 and 82% of the long-term precipitation rate for this period. In addition, in September and November 2015, and in 2017 in September-October, the high temperature regime was maintained – the average monthly temperature was higher than the long-term norm by 4.5 and 2.9°C and 3.5, respectively, 1.5 and 1.0°C (Table 5).
In autumn 2016, only in September the air temperature was higher by 1.6°C and in October and November – lower by 1.4 and 0.4°C.
Instead, in autumn 2018 and 2019, at the time of winter barley sowing, productive moisture reserves in the seed layer of the soil were 6-8 mm and were insufficient to obtain friendly seedlings, which required September 18 and 17 pre-sowing irrigation at 400 and 500 m^3/ha, in accordance. Thanks to watering and

Scientific Papers Series Management, Economic Engineering in Agriculture and Rural Development
Vol. 22, Issue 4, 2022
PRINT ISSN 2284-7995, E-ISSN 2285-3952

warm weather, the seedlings appeared on time.

Table 5. Meteorological indicators during the autumn vegetation of winter crops (data from the regional center for hydrometeorology in Kherson)

Years	Months			Average for the autumn period
	September	October	November	
average daily air temperature, ºC				
2013	15.1	9.3	7.5	10.6
2014	18.4	9.3	3.3	10.5
2015	20.9	9.4	7.3	12.5
2016	18.0	8.4	4.0	10.1
2017	19.9	11.3	5.4	12.2
2018	18.7	12.5	2.7	12.5
2019	18.1	11.6	7.1	12.3
Norm	**16.4**	**9.8**	**4.4**	**10.2**
the amount of precipitation, mm				
2013	43.7	53.9	4.0	101.6
2014	43.0	34.2	21.5	98.7
2015	4.6	18.6	44.2	67.4
2016	33.2	74.4	34.2	141.8
2017	0.7	12.0	40.6	53.3
2018	42.8	9.6	31.1	83.5
2019	13.0	62.0	38.0	113.0
Norm	**40.0**	**28.0**	**36.0**	**104.0**

Source: [27].

In general, the calendar autumn of 2019, as in 2018, was held at elevated temperatures, and the average air temperature was 12.3 and 12.5°C, respectively, which is on 2.1 and 2.3°C above the long-term norm. The amount of precipitation in the autumn of 2019 was 113 mm (109% of the seasonal norm), and in 2018 – 84 mm (81% of the seasonal norm). The amount of precipitation received during the period of «sowing-cessation of autumn vegetation» of different calendar terms differed significantly during the research years and ranged from 4.3 to 63.9 mm in 2013, from 27.9 to 87.0 mm – in 2014 from 57.2 to 65.3 mm– in 2015, from 23.7 to 98.0 mm – in 2016, from 93.3 to 96.0 mm – in 2017, from 6.1 to 22.1 mm – in 2018 and from 60.8 to 131.2 mm – in 2019.

Conditions were wet in 2016, when since September 20 and October 1, 10 and 20 until the cessation of vegetation of winter barley plants fell on 42.1 mm, 56.0, 28.9 and 0.7 mm more than the long-term average for 1945–2010. In 2013, 2015, 2017 and 2018, the amount of precipitation at all sowing dates was less than the long-term average. However, if in 2013 the largest shortage of precipitation was observed in the case of sowing on October 20 (-39.7 mm), then in 2015, 2017 and 2018 in the case of sowing on September 20 and October 1 – respectively: 50.7 and 36.7 mm, 36.3 and 23.0 and 31.5 and 30.0 mm.

Precipitation during the autumn vegetation in the case of sowing on September 20 and October 1 in 2019 exceeded the norm by 16.2 and 18.1 mm, respectively, but in the case of sowing on October 10 and 20 was lower than it by 26.2 and 21.2 mm. In 2014, the amount of precipitation in the case of sowing on September 20 and October 10 was higher than the long-term average by 20.2 and 3.2 mm, while in the case of sowing on October 1 and 20 it was lower by 6.8 and 5.9 mm. Thus, in the years of research there was a different supply of precipitation of winter crops in the autumn growing season (Table 6). According to the average long-term values, the cessation of active vegetation of winter grain crops in the Kherson region occurs on November 25. The actual duration of the autumn growing season differed markedly over the years of research.

Table 6. Hydrothermal conditions of the autumn period «sowing-cessation of autumn vegetation» of winter cereals depending on the timing of sowing

Year of sowing	Sowing period				
	September 20	October 1	October 10	October 20	
the amount of precipitation for the period «sowing-cessation of autumn vegetation», mm					
2013	63.9	57.9	40.0	4.3	
± from the norm	-9.1	-1.1	-9.0	-39.7	
2014	87.0	46.0	46.0	27.9	
± from the norm	+20.2	-6.8	+3.2	-5.9	
2015	65.3	65.3	64.9	57.2	
± from the norm	-50.7	-36.7	-27.1	-25.8	
2016	98.1	98.0	60.9	23.7	
± from the norm	+42.1	+56.0	+28.9	+0.7	
2017	96.7	96.0	93.4	93.3	
± from the norm	-36.3	-23.0	-15.6	-6.7	
2018	22.1	9.6	6.1	6.1	
± from the norm	-31.5	-30.0	-23.5	-14.5	
2019	131.2	119.1	64.8	60.8	
± from the norm	+16.2	+18.1	-26.2	-21.2	
Avarage	80.6	70.3	53.7	39.0	
± from the norm	-7.0	-13.4	-9.9	-16.2	
duration of the period «sowing-cessation of autumn vegetation», days					cessation of vegetation
2013	68	58	48	38	27. XI
2014	64	54	44	34	23. XI
2015	100	90	80	70	29. XII
2016	56	46	36	26	15. XI
2017	114	104	94	84	12. I
2018	54	44	34	24	13. XI
2019	100	89	78	69	28. XII
average for 2013–2021	79	69	59	49	8. XII
average perennial for 1945–2010	66	56	46	36	25.XI

Source: [27].

In 2013 and 2014, the cessation of winter wheat vegetation took place on November 27 and 23, which is close to the long-term average. In 2015 and 2017, there was a long vegetation of winter crops, which ended only on December 29 and January 12, respectively.

This temperature regime led to an extension of the growing season by 30 and 45 days relative to long-term values. The opposite situation was observed in autumn 2016, when winter crops stopped growing on 11 days earlier than long-term values – November 15, and December was on 1.1°C colder than normal. In 2018, the decrease in temperature on November 13 suspended the vegetation of winter crops for a week and a half earlier than usual. Much warmer weather conditions were observed in November and December 2019, so winter wheat plants did not stop their growing season. The maximum air temperature in December reached 11-14°C of heat, while the minimum was 3-7°C of frost. The average air temperature in December was +4.3°C, which is on 4.2°C above the climatic norm. During 137 years of meteorological observations, such a high average monthly air temperature was observed only in 1886, 1901 and 1960, when the warmest nights were recorded on December 22 and 24 – over +10.8°C and 6.6°C. According to observations, +6.1°C was recorded in December 1960 and +6.3°C in 2014. At the end of the month, there was a gradual decrease in air temperature at night to 0.4-1.8°C of frost, due to why winter crops stopped the growing on December 28, 2019.

Long-term observations in the steppe zone have shown that the duration of autumn vegetation should be 40-50 days to prepare barley for winter conditions. For the normal development of plants from germination to the end of the growing season, 200-300°C of effective temperatures at values of biological zero +5°C are required. This amount of effective temperatures helps plants to form sufficient biomass and the amount of sugars needed for successful overwintering [5, 14].

For sowing in the period from September 20 to October 20, the duration of the autumn growing season in 2013 and 2014 was within close to the optimal values and amounted to 68-34 days. Also close to each other was the duration of autumn vegetation of winter wheat plants in 2016 and 2018, but the shortest duration for all years of research – 56-26 days and 54-24 days, respectively. In 2015 and 2019, at the specified sowing dates, the duration was 100-70 and 100-69 days.

The longest autumn growing season was in 2017, which was 114-84 days. Studies conducted in 2015-2018 with sowing dates show a better autumn development of barley plants than 15 years later.

Thus, for sowing in the period from September 20 to October 1, full seedlings appeared for 9-10 days, for sowing on October 10 and 20 – for 16 and 23 days (Table 7).

Table 7. Duration of autumn vegetation of winter barley and the sum of temperatures for this period depending on the sowing period (average for 2015-2017)

Sowing period	Duration (days)		The sum of temperatures for the period, ° C	
	sowing – seedlings	sowing – the cessation of autumn vegetation	sowing – seedlings	sowing – the cessation of autumn vegetation
September 20	10	90	169	741
October 1	9	80	110	564
October 10	16	70	156	451
October 20	23	60	166	325

Source: [27].

In the case of sowing on September 20, the vegetation of plants lasted an average of 90 days in autumn, and the sum of average daily temperatures was 741°C, but in the case of sowing on October 20, these figures decreased to 60 days and 325°C, respectively. Significant influence of sowing dates on growth and development of plants in autumn, their bushiness is noted.

During the first sowing period (September 20) the most intensive growth processes and tillering of plants took place, while in the crops of the second (October 1) and the third sowing periods (October 10) they slowed down, and in the last period (October 20) – their inhibition was observed due to average daily air temperature. Varietal peculiarities were also manifested.

In the case of sowing on September 20, winter barley varieties Akademichnyi, Deviatyi val and Dostoinyi created an average of 3.8-4.4 shoots before entering the winter (Fig. 2).

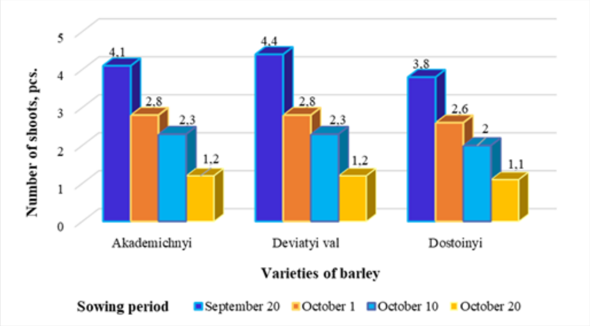

Fig. 2. Bushiness of winter barley varieties at different sowing dates (average for 2015-2017)
Source: [27].

In the case of sowing on October 1 and 10, the bushiness, on average for the years of research, was 2.6-2.8 and 2.0-2.3. At the same time, due to the long autumn vegetation in 2015 and 2017, the plants were at the beginning of the tillering phase on October 20, while they usually did not have time to start it. At the same time, the conditions of these years during the first sowing period led to excessive tillering. Among the varieties, tillering of the variety Deviatyi val was more intensive. The obtained data indicate that the sum of the average daily air temperatures of autumn vegetation for optimal development of winter barley plants should be 450-560°C. The timing of sowing significantly affected the preparation of plants for overwintering. This is very important, because winter barley does not have high winter hardiness and in some years, even in southern Ukraine, its crops are damaged by frost and liquefied, which leads to a significant reduction in yield. During the years of research, winters were favorable for overwintering winter barley, so it was not possible to determine the effect of sowing time and variety on winter hardiness of plants. However, it is known that there is a direct correlation between frost resistance and the content of soluble sugars in the nodes of winter barley tillering [3].
Our research also found that in the nodes of winter barley bushes, the most sugars accumulated during sowing on September 20 and October 1, and the least – on October 20. Thus, for sowing on September 20 and October 1, 2015, at the time of the cessation of autumn vegetation, 30.96-31.68 and 30.22-31.65% of sugars were in the nodes of tillering of plants, in 2016 – 38, 29-38.44 and 36.70-38.8% and in 2017 – 33.30-33.70 and 31.87-32.99%, in the case of sowing on October 20 their number was lower and amounted to 25.67-25.69%, 24.48-25.01 and 24.20-24.31%, respectively (Table 8).

Table 8. Sugar content in tillering nodes of winter barley before plants entrance in winter period and at the end of winter depending on the variety and sowing date

№	Variety	Sugar content on dry matter before plants entrance in winter period, %		
		03.12.2015	02.12.2016	04.12.2017
		sowing date September 20		
1	Akademichnyi	31.68	38.29	33.70
2	Deviatyi val	30.96	38.44	33.30
		sowing date October 1		
3	Akademichnyi	30.22	36.70	31.87
4	Deviatyi val	31.65	37.85	32.99
		sowing date October 10		
5	Akademichnyi	29.38	32.15	28.67
6	Deviatyi val	28.52	31.21	29.02
		sowing date October 20		
7	Akademichnyi	25.67	24.48	24.20
8	Deviatyi val	25.69	25.01	24.31

Source: [27].

The latter is due to the fact that in the case of sowing on October 20 the plants do not have time to accumulate enough sugars before winter and obtain good hardiness, especially in autumn 2016 and 2017. During this sowing period most sugars were in the variety Deviatyi val. That is, for high hardening of winter barley plants, the best time for sowing of the studied varieties is the beginning of October.

CONCLUSIONS

In the case of sowing on September 20, the vegetation of plants in autumn lasted an average of 82 days, and the sum of average daily temperatures was 724°C, of sowing on October 1 – 72 days and 540°C, for sowing on October 20 – 52 days and 330°C, respectively.
In the case of sowing winter barley on September 20, plants of all varieties had time to carry out tillering well in autumn, had a bushiness of 3.5-5.2, of sowing on October 1 the bushiness was 2.3-3.2, and for sowing on October 20 the plants did not have time for tillering, they entranced in winter in the phase of 2-3 leaves.
For high hardening of winter barley plants, the best sowing period of the studied varieties is the beginning of October, during which

30.22-38.8% of sugars accumulated in the bush nodes of plants during the cessation of autumn vegetation, which is on 5.74-13.11% more than in the case of sowing on October 20.

REFERENCES

[1]Ban, N., Caillaud, C., Coppola, E., Pichelli, E. 2021, The first multi-model ensemble of regional climate simulations at kilometer-scale resolution, part I evaluation of precipitation. DOI:10.1007/s00382-021-05708-w

[2]Berca, M., Horoias, R, 2022, NDMI use in recognition of water stress issues, related to winter wheat yields in Southern Romania, Scientific Papers Series Management, Economic Engineering in Agriculture and Rural Development, Vol.22(2), 105-111, https://managementjournal.usamv.ro/pdf/vol.22_2/Art12.pdf, Accessed on September 15, 2022.

[3]Bondarenko, A.S., Boyko, O.V., 2011, Dynamics of accumulation and consumption of carbohydrates by winter triticale plants depending on the timing of sowing in the northern part of the steppe of Ukraine. Bulletin of the Institute of Grain Management, № 40, p. 147–151.

[4]Campbell, L.G., Luo, L.G., Mercer, K.L., 2012, Effect of water availability and genetic diversity on flowering phenology, synchrony and reproductive investment in summer squash. doi: https://doi,org/10.1017/S0021859612000731.

[5]Ding, D.Y., Feng, H., Zhao, Y.,He, J.Q., Zou, Y.F., Jin, J.M., 2015, Modifying Winter Wheat Sowing Date as an Adaptation to Climate Change on the Loess Plateau. Published in Agron. J. 107:1–11. doi:10.2134/agronj15.0262.

[6]Hewitt, C.D., Guglielmo, F., Joussaume, S., Bessembinder, J., Christel, I., Doblas-Reyes, F.J., Djurdjevic, V., Garrett, N., Kjellström, E., Krzic, A., Máñez, C. M., St. Clair, A.L. 2021, Recommendations for Future Research Priorities for Climate Modeling and Climate Services. Bulletin of the American Meteorological Society, Volume 102: Issue 3. Page(s): E578–E588. DOI: https://doi.org/10.1175/BAMS-D-20-0103.1.

[7]Iles, C.E., Vautard, R., Strachan, J., Joussaume, S., Eggen, B.R., Hewitt, C.D., 2020, The benefits of increasing resolution in global and regional climate simulations for European climate extremes. https://doi.org/10.5194/gmd-13-5583-2020.

[8]IOP Conf. Series: Earth and Environmental Science 839. 2021, 022059 IOP Publishing doi:10.1088/1755-1315/839/2/022059.

[9]Jonghan, Ko., Chi, T.Ng., Seungtaek, J., Jun-Hwan, K., Byunwoo, L., Han-Yong, K., 2019, Impacts of regional climate change on barley yield and its geographical variation in South Korea. Int. Agrophys, 33(1): 81–96, DOI: https://doi.org/10.31545/intagr/104398ю.

[10]Kiriyak, Y.P., Kovalenko, A.M., 2015, Climate change and fluctuations in the southern steppe zone of Ukraine and its possible consequences for grain production. Irrigated agriculture: interdepartmental thematic scientific collection, Vol. 63, pp. 86–89.

[11]Kovalenko, A. 2015, Increasing aridity climate of southern steppe of Ukraine. Its effects and remedies, 3rd UNCCD Scientific Conference, 9-12 March, Cancun. Mexico: Book of Abstracts, pp. 293–294.

[12]Lalić, B., Sremac, A.F., Dekić, L., Eitzinger, J., Perišić, D., 2018, Seasonal forecasting of green water components and crop yields of winter wheat in Serbia and Austria. J Agric Sci. 2018 Jul; 156(5): 64 657. doi: 10.1017/S0021859617000788

[13] Litvinov, D., Litvinova, O., Butenko, A., Masyk, I., Onychko, V., Khomenko, L., Terokhina, N., Kharchenko, S. 2020, The Typicality of Hydrothermal Conditions of the Forest Steppe and Their Influence on the Productivity of Crops. Journal of Environmental Research, Engineering and Management Vol. 76 (3), 84–95 DOI 10.5755/j01.erem.76.3.25365.

[14]Lykov, S.V. 2006, Ways to adapt the elements of technology for growing winter barley in the foothills of the Crimea. Abstract of the dissertation for the degree of Candidate of Agricultural Sciences Science. Simferopol: PF "KATU" NAU, p. 24.

[15]Marcinkowski, P., Piniewski, M., 2018, Effect of climate change on sowing and harvest dates of spring barley and maize in Poland. Int. Agrophys. 2018, 32, 265-271 doi: 10.1515/intag-2017-0015

[16]Manukyan, I.R., Basieva, I.A., Gneush, A.N., Arutyunova, G.Y., Udychak, M.M., Yurin, D.A., 2019, Complex evaluation of productivity and environmental plasticity of the winter whaeta breeding material for the conditions of the submontane zone of Central Caucasus, Scientific Papers Series Management, Economic Engineering in Agriculture and Rural Development, Vol.19(4), 159-165. https://managementjournal.usamv.ro/pdf/vol.19_4/Art23.pdf, Accessed on September 15, 2022.

[17]Martel, J.,Mailhot, A., Brissette, F., 2020, Global and Regional Projected Changes in 100-yr Subdaily, Daily, and Multiday Precipitation Extremes Estimated from Three Large Ensembles of Climate Simulations. Journal of Climate. Page(s): 1089–1103. DOI: https://doi.org/10.1175/JCLI-D-18-0764.1

[18]Neverov, A., Abdrashitov, R. 2021, Trends in regional climate change and field crop productivity in Orenburg steppe region. doi:10.1088/1755-1315/839/2/022059

[19]Raftery, A.E., Zimmer, A., Frierson, D.M.W., Startz, R., Liu, P., 2017, Less than 2°C warming by 2100 unlikely. Nat. Clim. Change 7:637–41. doi: 10.1038/nclimate3352.

[20]Sandhu, S., Kaur, P., Gill, K.K., Vashisht, B.B., 2020, The effect of recent climate shifts on optimal sowing windows for wheat in Punjab, India, Journal of Water and Climate Change 11(1), DOI:10.2166/wcc.2019.241

[21] Solodushko, M.M., Solodushko, V.P., Hasanova, I.I., Yaroshenko, S.S., Romanenko, O.L., 2019, Influence of terms of sowing of winter barley after various predecessors on its productivity. Agronomist, 9, p. 12-21.

[22]Trnka, M., Olesen, J.E., Kersebaum, K.C., Skjelvåg,A.O., 2011,Agroclimatic conditions in Europe under climate change. Global Change Biology. 17, 2298–2318, doi: 10.1111/j.1365-2486.2011.02396.x.

[23]Vozhegova, R.A., Kiriyak, Y.P., Zaiets, S.O. et al., 2018, Innovations in technologies for growing winter and spring crops of the 2018 harvest in the Dry Steppe subzone: scientific and practical recommendations. Kherson: OLDI-PLUS, p.134.

[24]Vozhegova, R., Borovik, V., Konovalova, V., 2020, Yield and seed quality of oilseed flax varieties in the Southern Steppe of Ukraine depending on different growing conditions. Bulletin of Agricultural Science. Volume 98:3 DOI: https://doi.org/10.31073/agrovisnyk202003-12

[25]Zaiets, S.O., Kisil, L.B., 2018, Growth and development of winter barley varieties in autumn depending on hydrothermal conditions, sowing dates and growth regulators. Irrigated agriculture: Interdepartmental. topic. Science. coll., 70:13-16.

[26]Zaiets, S.O., Kisil, L.B., 2019, Autumn growth and development of winter barley plants on irrigated lands depending on hydrothermal conditions, variety, sowing dates and growth regulators. Bulletin of Agricultural Science, p. 59-64.

[27]Zaiets, S.O., Scientific foundations of the formation of adaptive technologies for the cultivation of grain crops and soybeans on the irrigated lands of the Southern Steppe of Ukraine: author's abstract. Thesis ... doctor of agricultural sciences: 06.01.02. National Academy of Agrarian Sciences of Ukraine, Institute of Irrigated Agriculture. Kherson, 2021. 48 p.