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Influence of irrigation and weather conditions on the duration of interphase periods of winter wheat varieties

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Abstract. The autumn growth and development of plants depend on a complex of external factors: the average daily air temperature, the amount of precipitation, the humidity of the seed layer of the soil, nutrients, light, etc. If winter wheat is sown at a later date, there are risks that the plants will enter the winter not well developed. It is possible to accelerate the passage of interphase periods with the help of irrigation, which is a necessary agrotechnical measure in the Southern Steppe of Ukraine. The purpose of the research is to establish the influence of varietal characteristics, irrigation and weather conditions on the duration of interphase periods of winter wheat in the autumn period on an international scale. Experimental research was carried out during 2020-2021 on southern chernozem, on the basis of the Educational Scientific and Practical Center of the Mykolaiv NAU with two varieties of winter wheat. Field, laboratory and comparative calculation methods were used during the research. The establishment and conduct of experiments were carried out according to the methodology of the research case. Soil moisture was determined by the thermogravimetric method, and phenophases were determined simultaneously throughout the experiment. It was determined that irrigation for 1-2 days reduces the duration of the interphase period of BBCH 00-09; for 3 days – BBCH 10-12; for 11 days – BBCH 13-19; for 5-7 days – BBCH 20-22. In natural conditions (without irrigation), the duration of the interphase periods (from BBCH 00-09 to 20-22) of the growth and development of plants of the studied varieties of winter wheat in 2020 was 93-96 days, which is 23-25 days more than in 2021. In plants of the Ovid variety under conditions of natural moisture (without irrigation), the interphase periods came 1-3 days later than in the Duma Odeska variety, while under irrigation conditions there was no significant difference. The obtained scientific results of the research will contribute to the wider implementation of irrigation, which will ensure the rapid and full growth and development of winter wheat plants in the autumn period, which will further contribute to increasing the yield and gross harvest of grain

Keywords: irrigation, sum of effective temperatures, sum of precipitation, soil moisture, Triticum aestivum

INTRODUCTION

The steppe region of Ukraine is the center of food production, mainly winter wheat and other food crops. The climatic conditions of the region are characterized by a high degree of aridity with an insufficient amount of precipitation and an uneven distribution during the growing seasons, which is often complicated by an increase in temperature. That is, the productivity of winter wheat largely depends on agroclimatic conditions in the year of sowing [1].

Wheat is the main crop in many countries of the world, as well as the main food crop in the Steppe zone, so the system of agrotechnical measures should be aimed at creating more favorable conditions for obtaining high productivity [2; 3]. Its growth characteristics at different phases of development, especially in autumn, are of great importance for the formation of the productivity of winter wheat plants [4].

One of the diagnostic signs that indicate growing conditions is plant growth. Growth processes, development of vegetative and reproductive organs are largely determined by providing plants with moisture

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and nutrients. It is known that there is a direct relationship between the yield, vegetative mass and height of plants, since stems and leaves are organs of transportation of mineral and organic substances [5].

Optimal growth and development of winter wheat plants depends on the combination of hydrothermal and soil conditions, the individual response of the crop to environmental factors, as well as the proper condition of the seed layer in autumn [6].

In the Steppe of Ukraine, almost every year during the sowing of winter wheat seeds, it is negatively affected by the lack of moisture. Often, sowing has to be done in semi-moist soil, which is the reason for low field seed germination. In addition, seedlings exhausted by drought suffer more from diseases, which constantly becomes crucial for successful overwintering of plants and obtaining a stable harvest [7].

With economic growth, continuous global environmental degradation, and increasing scarcity of water resources, droughts are becoming more frequent and have a significant impact on both regional ecology and sustainable economic development [8]. Water is a key limiting factor in agriculture. The shortage of water resources has become a serious threat to global food security [9].

Limited rainfall and water shortage are the main problems for winter wheat production in arid and semi-arid areas of northwestern China [9]. The North China Plain is the dominant winter wheat production area and the main grain production area in China. As a result of the shortage of water resources, the inconsistency of the spatial arrangement of water and land resources, the gap between the growth period of wheat plants and the time of precipitation, irrigation became the key to the development of agriculture in the region [10].

During abiotic stresses, physiological and biochemical changes in cells suppress plant growth and development, which ultimately reduces wheat yield. To ensure the food and nutritional security of the ever-growing world population, new approaches are needed for sustainable wheat production in the face of climate change, one of which is the creation of wheat varieties resistant to abiotic stress through molecular selection, rapid selection, genetic engineering, and improvement of existing technologies [11].

Therefore, irrigation itself, especially in the South of Ukraine, can neutralize the negative impact of the autumn drought on the rapid and friendly germination of seeds and obtaining full-fledged seedlings of winter wheat, which is a necessary condition for the formation of highly productive crops.

The main goal of the research is to determine the influence of irrigation and weather conditions on the duration of interphase periods of winter wheat varieties according to the VVSN scale in the autumn period.

LITERATURE REVIEW

A significant amount of research has been devoted to the question of the influence of irrigation and weather conditions on the duration of interphase periods for the cultivation of winter wheat varieties in the conditions of Southern Ukraine.

Breeding achievements of recent decades have significantly increased the genetic level of productivity of modern winter wheat varieties [12]. However, the issue of adaptation and stability of the yield level remains one of the biggest problems of increasing the level of realization of the biological potential of the created varieties in different climatic zones [13]. The determining criterion for the selection of modern varieties of winter wheat is the degree of intensity and response to growing conditions. Each variety has certain morpho-agrobiological features and properties, thanks to which it is able to realize its genetic potential if a favorable environment is created for it [14].

The yield of wheat varies depending on the year of cultivation, the influence of climatic conditions, the variety, applied nutrients, the presence of pests and pathogens [15-17].

In the south of Ukraine, agricultural producers should pay more attention to the accumulation of moisture in the soil and better use it as a factor that most affects the yield of agricultural crops, including winter cereals. All life processes are connected with the movement of water in plant organs. In addition, soil moisture determines the level of vital activity of not only plants, but also microorganisms, ensures the intensity of many physical and chemical processes. Due to global warming and climate change, moisture becomes the main limiting factor in the productivity of agricultural crops [18].

O. Lavrynenko *et al.* [19] determined that in the steppe zone of Ukraine, against the background of general climate change, the realization of the potential productivity of common wheat varieties may be limited by various limiting factors, and one of the main ones is moisture availability. Adaptability to the soil and climatic conditions of the Steppe zone, which is characterized by an acute moisture deficit, high temperatures in summer, and a long frost-free period, is the main requirement for winter wheat varieties *Triticum aestivum* L. of the steppe ecological group. Artificial irrigation prevents the increase of production processes, improves the microclimate of phytocenosis, but in the south of Ukraine it does not completely solve the problem of grain formation due to high temperatures and low relative humidity.

Research by B.V. Blyznyuk *et al.* [20] it was determined that the duration of the growing season as an important biological feature of winter wheat depends on both the genotype and the growing conditions of the variety. During the growing season, plants go through

the corresponding phases of development associated with the formation of new organs. Depending on the temperature, moisture, lighting, availability of nutrients, the time required for the formation and ripening of the crop is different. The vegetation cycle of winter wheat is divided into two main periods: germination-earing and earing-ripening. In the creation of a winter wheat crop, the main thing is the period of seedling-earing, during which the plants go through 8 out of 11 stages of organogenesis and on which the future productivity and precocity of the variety depends.

According to the results of research conducted in 2016/2017 in Kazakhstan, it was determined that the duration of the phenological phases of growth and development of winter wheat has a significant impact on air temperature and soil moisture. In irrigated areas, wheat seedlings appeared earlier than in non-irrigated ones [21].

As you can see, many scientists have been studying this topic, but varieties and weather conditions change. In addition, scientists determined the interphase periods without using the BBCH international scale, thanks to which it is possible to follow the growth and development of plants in more detail.

MATERIALS AND METHODS

The research was conducted during 2020-2021 at the research field of the Educational-Scientific-Practical Center of the Ukrainian National Academy of Sciences (Bladhorivka village, Mykolaiv district, Mykolaiv region). The object of research was winter wheat: Ovidii and Duma Odeska varieties.

The soil is represented by southern chernozem, residual-slightly saline heavy loam on loess with humus content in the 0-30 cm layer from 3.1 to 3.3%. The reaction of the soil solution is neutral (pH – 6.8-7.2). Mobile forms of nutrients in the arable layer of the soil contained on average: nitrates (according to Grandval Lazhe) – 15-25, mobile phosphorus (according to Machigin) – 41-46, exchangeable potassium (on a flame photometer) – 389-425 mg/kg of soil.

Experiments were carried out according to the following schemes: varieties of winter wheat (factor A) – Ovid and Duma Odesa; irrigation (factor B) – without irrigation (control) and under irrigation conditions.

The total area of the plot is 50 m^2, the registered area is 26 m^2. The experiment was repeated three times. Placement of experimental plots is consistent. Sowing of winter wheat was carried out on October 1 with a sowing rate of 4.5 million units/ha. Agricultural machinery in the experiment was generally accepted for the Steppe zone of Ukraine, except for the agricultural measures taken for research.

The material for the research was two varieties of soft winter wheat, the owners of which are the leading scientific institutions of Ukraine: Duma Odesa and Ovidy (Breeding and Genetic Institute – National Center for Seed Science and Varietal Research of the Ukrainian Academy of Agrarian Sciences), which are registered in the State Register of Plant Varieties Suitable to distribution in Ukraine in 2017.

Field and comparative calculation methods were used to conduct experimental work. Establishment and conduct of experiments, selection of soil samples, and their preparation for analysis were carried out in accordance with the methodology of the research case, methodological instructions and DSTU [22]. Soil moisture was determined by the thermogravimetric method – in the 0-100 cm layer every 10 cm [22]. Samples were taken before sowing and during the vegetation phase of the crop. Definitions are repeated twice.

Data from the Austrian-made Pessl Instruments Weather Station (iMETOS), which not only provides highly accurate local weather data, but also provides a 6-day weather forecast, was used to analyze agroclimatic conditions. The weather station is equipped with sensors that determine the following parameters: precipitation, air and soil temperature, humidity level of air, soil and leaves, wind speed and others.

In the main phases of growth and development of plants, phenological observations were carried out in accordance with the "Methodology of state variety testing of crops" [23]. The beginning of the phase was recorded when it occurred in 10% of the plants, and the complete phase was recorded in 75% of the plants. Phenophases were determined simultaneously throughout the experiment.

Harvest accounting is carried out continuously from the entire accounting area. Harvesting of winter wheat was carried out with a SAMPO-500 combine. After threshing, the thresher of the grain harvester is closed at each point, the collected grain is weighed and brought to standard humidity (14%) and purity (100%).

Research results obtained in the form of analysis of digital materials are processed by the statistical and mathematical method of dispersion and variation analyzes using Microsoft Excel and Agrostat computer programs.

RESULTS AND DISCUSSION

Researching the topic, the authors determined that the interphase period "Macrostage 0: Germination (VVSH 00-09) Dry seed – seedling, emergence of the cotyledon to the soil surface" of winter wheat lasted longer in 2021 and amounted to 13-17 days depending on the variety and moisture conditions, which by 1-6 days more than in 2020 (Table 1).

Table 1. *Characteristics of the interphase period "Macrostage 0: Germination of VVSH 00-09" of winter wheat depending on the variety and moisture conditions*

Indexes	Without irrigation (factor B)		Under irrigation conditions (factor B)	
	Variety (factor A)			
	Ovid	Duma of Odesa	Ovid	Duma of Odesa
2020 year				
Duration of the interphase period, days	11	10	9	9
Average air temperature, °C	17.3	17.2	17.1	17.1
Minimum air temperature, °C	6.5	6.5	6.5	6.5
Maximum temperature, air, °C	25.7	25.7	25.7	25.7
Sum of effective temperatures, °C	135.4	122.2	109.0	109.0
Amount of precipitation, mm	0.8	0.6	0.4	0.4
Soil moisture, %	23.2	23.4	46.5	46.5
Average soil temperature, °C	17.6	17.6	18.5	18.5
2021 year				
Duration of the interphase period, days	17	16	13	13
Average air temperature, °C	9.8	9.6	9.2	9.2
Minimum air temperature, °C	-0.4	-0.4	0.2	0.2
Maximum temperature, air, °C	23.3	23.3	16.8	16.8
Sum of effective temperatures, °C	84.0	74.3	47.5	47.5
Amount of precipitation, mm	48.2	47.4	47.0	47.0
Soil moisture, %	21.5	21.2	47.1	47.1
Average soil temperature, °C	11.4	11.3	14.8	14.8

Source: *developed by the authors*

This can be explained by the fact that productive precipitation fell only on October 13, that is, 7 days after sowing, which affected the duration of seed germination.

Thus, the duration of the interphase period of VVSH 00-09 winter wheat plants ranged from 10 days in the Duma Odeska variety (2020) to 17 days in the Ovid variety in the version without irrigation.

The weather conditions of 2020 were more favorable for the germination of winter wheat seeds. So, the average daily air temperature was 17.1-17.3°C, minimum – 6.5°C, maximum – 25.7°C. The plants managed to accumulate the sum of effective temperatures from 109.0°C (Ovidii and Duma Odeska varieties under irrigation conditions) to 135.4°C (Ovidii variety in the version without irrigation).

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It was determined that the moisture content of the seed layer of the soil has a greater effect on the germination rate of winter wheat seeds when grown without irrigation than the amount of precipitation during the reporting period. Thus, in 2020, during the interphase period Macro stage 0: Germination of VVSH 00-09, 0.6-0.8 mm of precipitation fell, and the soil moisture was 23.2-23.4%, while in 2021 – 47.4-48.2 mm and 21.2-21.5%.

It was determined that the soil temperature during the studied interphase period under irrigation conditions was higher and amounted to 14.8°C (2021) and 18.5°C (2020), which is 5.1% and 23.6% higher, than without irrigation.

Soil moisture was higher in 2021 – 47.1% (under irrigation conditions), which is 25.6% more than in the case without irrigation.

Therefore, it can be concluded that the weather conditions for the initial growth and development of winter wheat seeds of the studied varieties were favorable, which made it possible to obtain full-fledged seedlings.

The interphase period of winter wheat according to the VVSH 10-12 scale in 2021 was characterized by a sufficient amount of precipitation and its uniform fall with a total amount of 17.8 mm in the non-irrigated version and 13.6 mm in the irrigation conditions. The duration of the reported interphase period ranged from 16 (under irrigation conditions) to 19 days (without irrigation) (Table 2).

Table 2. *Characteristics of the interphase period "Macrostage 1: Development of leaves VVSH 10-12" of winter wheat depending on the variety and moisture conditions*

Indexes	Without irrigation(factor B)		Under irrigation conditions (factor B)	
	Variety (factor A)			
	Ovid	Duma of Odesa	Ovid	Duma of Odesa
2020 year				
Duration of the interphase period, days	17	17	14	14
Average air temperature, °C	11.3	11.8	11.6	11.6
Minimum air temperature, °C	0.1	0.1	0.1	0.1
Maximum temperature, air, °C	21.7	21.7	21.7	21.7
Sum of effective temperatures, °C	106.6	116.0	91.8	91.8
Amount of precipitation, mm	3.8	4.0	3.8	3.8
Soil moisture, %	18.0	18.2	45.9	45.9
Average soil temperature, °C	13.3	13.7	16.5	16.5
2021 year				
Duration of the interphase period, days	18	19	16	16
Average air temperature, °C	8.2	7.8	9.1	9.1
Minimum air temperature, °C	-2.0	-3.0	-1.6	-1.6
Maximum temperature, air, °C	18.6	18.6	18.6	18.6
Sum of effective temperatures, °C	61.3	68.2	71.2	71.2
Amount of precipitation, mm	17.8	17.8	13.6	13.6
Soil moisture, %	26.6	26.7	46.6	46.6
Average soil temperature, °C	9.8	9.5	12.9	12.9

Source: *developed by the authors*

The interphase period of VVSH 10-12 in 2020 was shorter (14 days) in winter wheat varieties under irrigation conditions, which is 3 days less than in non-irrigated options and 2-5 days less than in 2021. Average air temperature ranged from 7.8°C (2021) to 13.2°C (2020) in the version without irrigation. The minimum air temperature for the reporting period ranged from minus 1.6-3.0°C (2021) to 0.1°C (2020), and the maximum – 18.6 (2021) and 21.7°C (2020), respectively.

It should be noted that winter wheat plants under irrigation reached the sum of effective temperatures from 71.2°C (2021) to 115.3°C (2020), while without irrigation – 61.3-68.2°C (2021) and 106.6-116.0°C (2020) depending on the variety.

Soil moisture in non-irrigated areas ranged from 18.0 to 26.7%, while in irrigated areas it was 46.1-46.6%, which contributed to better development of winter wheat plants.

A research group of scientists from the Department of Earth Observation of Agriculture Canada [24] claim that knowing what happens to plants at a certain stage of growth, you can correctly plan their further development. It is at stage VVSN 13-19 that the plant switches from nutrition due to nutrient reserves in seeds to nutrition due to its own root system. If wheat overwinters at this stage, its sensitivity to low temperatures, stagnant moisture, and soil changes increases significantly.

Over the years of our research, the interphase period of VVSH 13-19 (phase 3 leaf – phase 4 and subsequent leaves) was from 15 to 35 days, depending on the moisture conditions (Table 3).

Table 3. *Characteristics of the interphase period "Macrostage 1: Development of leaves BVSH 13-19" of winter wheat depending on the variety and moisture conditions*

Indexes	Without irrigation(factor B)		Under irrigation conditions (factor B)	
	Variety (factor A)			
	Ovid	Duma of Odesa	Ovid	Duma of Odesa
2020 year				
Duration of the interphase period, days	35	35	15	15
Average air temperature, °C	2.9	3.0	7.9	7.9
Minimum air temperature, °C	-0.1	-0.1	-4.0	-4.0
Maximum temperature, air, °C	6.1	6.1	16.4	16.4

Table 3, Continued

Indexes	Without irrigation(factor B)		Under irrigation conditions (factor B)	
	Variety (factor A)			
	Ovid	Duma of Odesa	Ovid	Duma of Odesa
Sum of effective temperatures, °C	48.8	52.6	47.3	47.3
Amount of precipitation, mm	18.2	18.2	1.4	1.4
Soil moisture, %	17.8	17.8	45.3	45.3
Average soil temperature, °C	4.8	5.0	14.5	14.5
2021 year				
Duration of the interphase period, days	18	18	17	17
Average air temperature, °C	4.0	4.3	5.0	5.0
Minimum air temperature, °C	-6.6	-6.6	-6.6	-6.6
Maximum temperature, air, °C	14.2	14.2	14.2	14.2
Sum of effective temperatures, °C	12.7	11.8	23.1	23.1
Amount of precipitation, mm	16.4	17.0	6.6	6.6
Soil moisture, %	27.4	27.5	46.0	46.0
Average soil temperature, °C	5.1	5.1	10.6	10.6

Source: *developed by the authors*

Under irrigation conditions, the reporting period was shorter and lasted 15 (2020) and 17 days (2021), while without irrigation – 18 (2021) and 35 days (2020).

It was determined that the duration of the interphase period "Macrostage 1: Development of leaves of VVSH 13-19" of winter wheat was significantly influenced by the average daily air temperature and soil moisture. Thus, in 2020, the average air temperature during the growth and development of plants without irrigation was 2.9-3.0°C, the moisture content of the seed layer of the soil was 17.8 mm, which delayed the onset of the 13-19 phases of BVSH up to 35 days, while in 2021, in the same version of the experiment, this interphase period lasted 18 days. At the same time, the average daily air temperature was 4.0-4.3°C, and soil moisture was 27.4-27.5%, which is 1.1-1.3°C and 4.6-4.7%, respectively more than in 2020. These conditions contributed to better rooting of plants and their intensive growth and development.

Hydrothermal indicators in the interphase period of VVSH 13-19 under irrigation conditions differed significantly from the sum of effective temperatures under non-irrigation conditions and depended on the conditions of the year. Thus, in the dry year of 2020, winter wheat plants of the studied varieties gained a greater amount of effective temperatures (48.8-52.6°C) in the non-irrigated variants, which is 21.0-24.3°C more than in the irrigation conditions . On the contrary, the sum of the effective temperatures of winter wheat plants in 2021 was lower (23.1°C) under irrigation conditions, while without irrigation – 11.8-12.7°C depending on the variety.

After the formation of 3-4 leaves, wheat plants move to the tillering stage – from VVSN 13-14 to VVSN 21. The interphase period "Macrostages 2: Tending II Lateral shoot in the sheath of a leaf - the 2nd bud of the tufting appears" VVSH 20-22 in 2020 was characterized with a significant amount of precipitation – from 22.8 mm (Duma Odeska and Ovid varieties under irrigation conditions) to 54.8 mm (Ovid varieties) under growing conditions without irrigation (Table 4).

Table 4. *Characteristics of the interphase period "Macrostage 2: Bushing II VVSH 20-22" of winter wheat depending on the variety and moisture conditions*

Indexes	Without irrigation(factor B)		Under irrigation conditions (factor B)	
	Variety (factor A)			
	Ovid	Duma of Odesa	Ovid	Duma of Odesa
2020 year				
Duration of the interphase period, days	33	31	21	21
Average air temperature, °C	0.4	0.4	2.9	2.9
Minimum air temperature, °C	-22.0	-22.0	-6.2	-6.2
Maximum temperature, air, °C	20.3	20.3	20.3	20.3
Sum of effective temperatures, °C	37.4	37.4	35.9	35.9
Amount of precipitation, mm	54.8	31.2	22.8	22.8
Soil moisture, %	39.8	40.6	41.8	41.8

Table 4, Continued

Indexes	Without irrigation(factor B)		Under irrigation conditions (factor B)	
	Variety (factor A)			
	Ovid	Duma of Odesa	Ovid	Duma of Odesa
Average soil temperature, °C	2.2	2.3	7.2	7.2
2021 year				
Duration of the interphase period, days	18	17	17	17
Average air temperature, °C	5.5	5.3	5.5	5.5
Minimum air temperature, °C	-3.4	-3.4	-3.4	-3.4
Maximum temperature, air, °C	14.4	14.4	14.4	14.4
Sum of effective temperatures, °C	28.6	25.9	28.9	28.9
Amount of precipitation, mm	47.0	46.4	37.6	37.6
Soil moisture, %	34.0	34.1	45.4	45.4
Average soil temperature, °C	5.9	5.9	8.7	8.7

Source: *developed by the authors*

It should be noted that in the variants without irrigation, the duration of the interphase period VVSH 20-22 differed between the varieties by 2 days, and the shortest (31 days) was in the Duma Odeska variety, which may indicate its greater resistance to drought and less water consumption. In 2021, the difference in the duration of the reported interphase period between varieties was less noticeable (1 day). Under irrigation conditions, the plants of both studied varieties developed almost identically.

During our research, the weather conditions in the interphase period of VBSN 20-22 were favorable for the growth and development of winter wheat plants in 2021 compared to 2020. Thus, the average daily air temperature during the growth and development of plants in 2021 was 5.3 -5.5°C, while in 2020 – 0.4-2.9°C, depending on the variety and moisture conditions. However, in 2020, the air temperature rose to 20.3°C during the studied period, while in 2021 – to 14.4°C.

It was determined that under irrigation conditions the soil temperature is 2.8-5.1°C (47.5-227.3%) higher, depending on the variety and year of research, than without irrigation.

Plants gained the sum of effective temperatures of 35.9-37.4°C (2020) and 25.9-28.9°C (2021) with soil moisture of 39.8-41.8% and 34.0-45.4% depending on the studied factors. Therefore, hydrothermal conditions of winter wheat plants differed significantly in terms of soil moisture, which was 1.2-2.0% and 11.3-11.4% more than under conditions of natural moisture.

Thus, on average in 2020-2021, the duration of the interphase periods of winter wheat plants of the Ovid variety depended significantly on moisture conditions (Fig. 1).

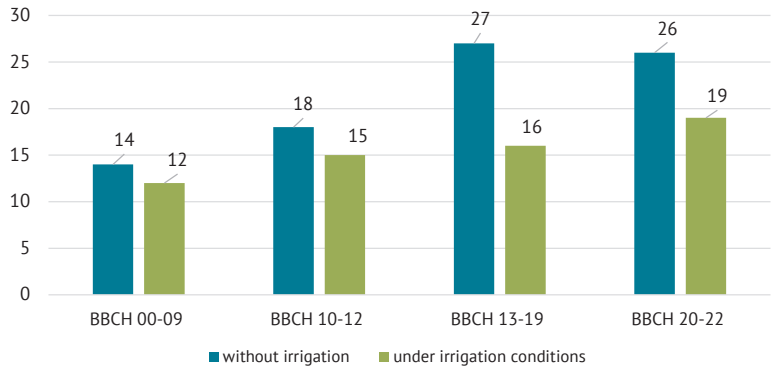

Figure 1. *The duration of the interphase periods of growth and development of winter wheat plants of the Ovid variety depending on moisture conditions (average for 2020-2021)*

Source: *developed by the authors*

The interphase periods (BBCH 00-09, BBCH 10-12, BBCH 13-19 and BBCH 20-22) in irrigated conditions were 1-11 days shorter than in non-irrigated areas.

In plants of the Duma Odeska variety, the duration of the studied interphase periods was shorter only in areas without irrigation compared to the Ovid variety. Under irrigation conditions, the duration of interphase periods did not differ between varieties (Fig. 2).

It was determined that irrigation led to a reduction of the interphase periods of BBCH 10-12, BBCH 13-19 and BBCH 20-22 by 3-11 days compared to plants in non-irrigated areas.

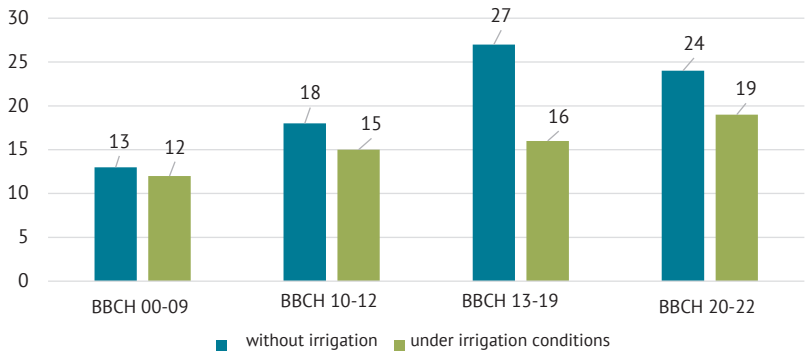

Figure 2. *Duration of interphase periods of growth and development of winter wheat plants of the Duma Odesa variety depending on moisture conditions (average for 2020-2021)*

Source: *developed by the authors*

The results of research conducted in 2020-2021 make it possible to state that the rate of emergence of seedlings is influenced by many factors: the average daily air temperature, the amount of precipitation, soil moisture and temperature, biological characteristics of the variety, etc. It was determined that from the beginning of the germination of winter wheat seeds to the appearance of seedlings, the sum of average daily temperatures averaged from 78.3 to 109.7°C, while V.A. Mazur *et al.* [25] claim that plants should gain the sum of effective temperatures from 60 to 90°C.

The average daily air temperature during the two years of research (2020-2021) during seed germination ranged from 13.2 to 13.6°C, which according to V. Gamayunova *et al.* [26] are the optimal parameters under which germination occurs intensively. However, the above-mentioned scientists did not take into account the influence of temperature and soil moisture on the intensity of seed germination.

Research conducted by M. Korkhova & V. Mykolaichuk [27] established that weather conditions during the vegetation phases of plants had a significant impact on the duration of interphase periods and crop formation in the conditions of the Southern Steppe of Ukraine of durum winter wheat varieties during 2014-2020. the duration of the "sowing-planting" period has the amount of precipitation. The duration of the period "seedlings-termination of vegetation", "emergence into the tube-beginning of earing" and "milk-wax maturity" depended to a greater extent on the sum of effective temperature and precipitation. The average daily air temperature has a greater effect on the duration of the rest period and the "restoration of spring bushing – exit to the tube".

The research of Yu.Yu. Chuprina *et al.* [28] found that the duration of the interphase period "sowing-seedling" of winter wheat was more influenced by the amount of precipitation, but the scientists did not take into account the moisture of the seed layer of the soil, which is a more important indicator. It was determined that, on average, over the years of research, the interphase period of BBCH 00-09 lasted from 13 to 14 days at a moisture content of the seed layer of the soil of 22.2-22.4 mm, while it lasted 11 days at a moisture content of 46.8 mm.

The results of the research conducted by M. Mostipan *et al.* [7] it was established that the productive reserves of water in the soil during spring renewal are critical for the formation of the winter wheat crop, and the later the spring renewal of winter wheat, the lower the productivity of the crop. The shorter the time between average daily temperatures above 0°C and the beginning of vegetative activity of plants, the greater the yield of winter wheat. Therefore, it is necessary to adjust agricultural techniques for growing winter wheat in spring and summer in accordance with the weather conditions of early spring and the time of plant vegetation recovery in spring.

Research conducted by K.A. Kazi also established that the germination rate of winter wheat seeds is affected by the moisture of the seed layer of the soil and the air temperature [21], the results showed that the optimal soil moisture should be 48%, and the air temperature should be 21.9°C under irrigation conditions, which is higher than with the results of our research, on average over two years by 1.2% and 5.2°C, respectively.

Soil temperature is also important for the germination of winter wheat seeds, the seed germination period was shorter (16 days) when the average soil temperature was 12.9-16.5°C. Research by V.P. Tkachuk & T.M. Tymoshchuk [29] this regularity is confirmed. On average, over 20 years of research, the duration of the interphase period of "Sivba-seedling" winter wheat was 16 days, and the soil temperature at a depth of 5 cm was 14.9°C.

Based on the results of three-year (2015/2016-2017/2018) research by T. Kolev *et al.* [30], carried out in the Experimental and Implementation Base of the Agrarian University (Plovdiv, Bulgaria) determined that the duration of the interphase period "Macrostage 1: Development of leaves of VVSH 10-12" of winter wheat

was 19 days and did not significantly depend on the average daily air temperature and the amount of precipitation. However, the above-mentioned scientists did not study other equally important meteorological factors that have a greater influence on the shortening or lengthening of this period. It was established that the duration of the interphase period of VVSH 10-12 was significantly influenced by soil moisture and temperature, and the amount of precipitation and air temperature was insignificant.

It was determined that the duration of the BBCH 20-22 interphase period of winter wheat of the studied varieties was 19-26 days depending on the moisture conditions. Research by A. Esaulko and others. [31] studied changes in the duration of interphase periods of winter wheat plant development in the arid zone of the Central Transcaucasia, which depended more on the sum of positive temperatures. It was established that positive temperature changes and drought lead to an increase in the length of growing seasons, a thinning of plant density and a decrease in the productivity of drought-resistant varieties.

Research conducted by V.V. Bezpalko *et al*. [32] and S. Turebayeva *et al*. [33] established that one of the most important periods of winter grain vegetation is the "trubbing" phase. During this period, lateral shoots and a secondary root system are formed from the underground nodes of the stem, that is, the organs that determine the yield of the crop are laid. Indicators of productive weeding depend on the conditions of the autumn-winter period. During the conducted studies, the interphase period of "seedlings-tillering" fell on the third decade of September and the first decade of October, the duration of the period ranged from 13 to 19 days, which was also confirmed by our research under irrigation conditions, but in variants without irrigation, the passage of this vegetation period increases to 25 days on average for the studied varieties.

Therefore, the studies of the above-mentioned scientists established a significant influence of weather conditions on the duration of interphase periods of autumn vegetation of plants of winter wheat varieties, but this issue has not been sufficiently studied under irrigation conditions. The effect of soil temperature and humidity on the length of reporting periods was almost not taken into account. Therefore, it is the new results of research with winter wheat varieties common in the South of Ukraine under conditions of irrigation and natural humidification that are relevant, especially under conditions of climate change.

CONCLUSIONS

As a result of field research conducted in 2020-2021, it was determined that the duration of the interphase period of BBCH 00-09 winter wheat plants was more influenced by the moisture content of the seed layer, which under irrigation was 46.5-47.1%, which by 23.1-25.9% more than without irrigation.

Under irrigation conditions, the interphase period of winter wheat (BBCH 10-12) was reduced by 2-3 days, compared to the same variants without irrigation. The development of leaves (BBCH 13-19) under irrigation conditions for 1-20 days, depending on the year of research, occurred faster than without irrigation. In 2021, the duration of the BBCH 20-22 interphase period did not differ significantly in the non-irrigated and irrigated options, while in 2020 it was 10-12 days longer than in the irrigated options. Interphase periods in winter wheat plants of the Ovid variety were 1-3 days longer than those of the Duma Odeska variety when grown without irrigation.

In connection with the increase of the average daily air temperature in the Steppe of Ukraine by 1-2°C, which leads to the shift of sowing dates to later dates (1st decade of October), the obtained scientific results should be taken into account by the product manufacturers at the sowing company, namely: start sowing winter wheat without irrigation follows the Ovid variety, which has a longer development period than the Duma Odeska variety, while under irrigation conditions this difference is less noticeable. Taking into account the scientific achievements of other researchers of the topic, further research is needed to study the influence of irrigation and weather conditions on the duration of interphase periods according to the BBCH scale and the productivity of the investigated winter wheat varieties.

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Вплив зрошення та погодних умов на тривалість міжфазних періодів сортів пшениці озимої

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Анотація. Осінній ріст і розвиток рослин залежать від комплексу зовнішніх факторів: середньодобової температури повітря, кількості опадів, вологості посівного шару ґрунту, поживних речовин, світла тощо. За сівби пшениці озимої у більш пізні строки є ризики, що рослини увійдуть в зиму не добре розвиненими. Прискорити проходження міжфазних періодів можна за допомогою зрошення, що є необхідним агротехнічним заходом в Південному Степу України. Мета досліджень – встановити вплив сортових особливостей, зрошення та погодних умов на тривалість міжфазних періодів пшениці озимої в осінній період за міжнародною шкалою. Експериментальні дослідження проводилися впродовж 2020-2021 рр. на чорноземі південному, на базі Навчального науково-практичного центру Миколаївського НАУ з двома сортами пшениці озимої. Під час дослідження використано польовий, лабораторний та порівняльно-розрахунковий методи. Закладання та проведення дослідів проводили згідно методики дослідної справи. Вологість ґрунту визначали термостатно-ваговим методом, а фенофази – окомірним одночасно у всьому досліді. Визначено, що зрошення на 1-2 доби скорочує тривалість міжфазного періоду ВВСН 00-09; на 3 доби – ВВСН 10-12; на 11 діб – ВВСН 13-19; на 5-7 діб – ВВСН 20-22. В природних умовах (без зрошення) тривалість міжфазних періодів (від ВВСН 00-09 до 20-22) росту та розвитку рослин досліджуваних сортів пшениці озимої у 2020 р. становила 93-96 діб, що на 23-25 діб більше, ніж у 2021 р. У рослин сорту Овідій в умовах природного зволоження (без зрошення) міжфазні періоди наставали на 1-3 доби пізніше, ніж у сорту Дума одеська, тоді як в умовах зрошення – без істотної різниці. Отримані наукові результати досліджень сприятимуть ширшому впровадженню зрошення, яке забезпечить швидкий та повноцінний ріст і розвиток рослин пшениці озимої в осінній період, що в подальшому сприятиме підвищенню врожайності та валових зборів зерна

Ключові слова: зрошення, сума ефективних температур, сума опадів, вологість ґрунту, *Triticum aestivum*