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THE IMPACT OF CHANGING WEATHER CONDITIONS ON THE YIELD OF FIELD CROPS IN THE LEFT-BANK FOREST-STEPPE OF UKRAINE

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Abstract. *Different weather. conditions affect plant growth rates, nutrient mobility in the soil, photosynthesis intensity, and soil biota activity. Optimization of soil water-air and nutrient regimes through land reclamation makes it possible to significantly offset the negative effects of adverse weather conditions and increase the sustainability of agrophytocenosis productivity. However, in the conditions of "organic" farming in regions with a moisture deficit without sufficient water resources and mineral fertilizers, effective agricultural production is problematic. Establishing the patterns of the influence of moisture and heat conditions at certain stages of organogenesis is the theoretical basis for increasing the sustainability of agriculture, in particular when using only natural soil fertility and secondary biomass. The aim of the work was to establish the patterns of changes in the yield of field crops in different crop rotations depending on the dynamics of agrometeorological factors in conditions of insufficient moisture in the eastern Forest-Steppe of Ukraine and to assess the productivity potential of crops, taking into account the annually changing hydrothermal conditions in the system "organic" farming system without the use of mineral fertilizers. The assessment of changes in agrometeorological resources was carried out using mathematical and statistical analysis of ten-day indicators of heat supply (air temperature and precipitation) and field crop yields. Data from a 20-year stationary experiment were processed using correlation and computational-comparative analysis methods with systematic generalization. The most reliable key periods before vegetation and during organogenesis were established, when the relationship between weather conditions and crop yields manifests itself with a sufficient level of reliability. The proposed approach is based on the formation of statistical series of yield data (15–20 years) and corresponding decadal indicators of temperature and precipitation in the local area. It is recommended to first construct graphs of the dynamics of hydrothermal conditions in years with different yields to identify periods of the most obvious deviations, and then conduct a detailed search for mathematical dependencies of productivity on weather conditions.*

Keywords: *correlation, hydrothermal conditions, field crops, yield, natural soil fertility background, organic production*

Relevance of the study. Weather conditions are one of the key factors determining annual fluctuations in crop yields and, consequently, the effectiveness of management decisions in the agricultural sector [1–5]. The productivity of agricultural land is influenced by a whole range of interrelated factors: rational crop rotation, soil availability of nutrients, its agrophysical characteristics, the condition and diversity of the soil biota, the biological properties of the varieties and hybrids used, the level of organic and mineral fertilizers applied, as well as climatic and agrometeorological conditions [6–8]. The latter often play a decisive role [9–11].

Analysis of recent studies and publications. Long-term stationary agrotechnical experiments [12–17] demonstrate that due to constant annual changes in weather conditions, yield indicators can vary significantly even within the same soil and climatic region. It is known that among the most effective factors ensuring the growth of productivity and adaptability of agroecosystems, various forms of land reclamation, primarily hydrotechnical and agrochemical, occupy an important place. Improving soil moisture, aeration, and nutrition regimes usually makes it possible to partially compensate for the negative impact of unfavorable atmospheric conditions and increase the stability of agricultural technologies [18]. However, in conditions of insufficient natural moisture, lack of water resources, and the inability to use fertilizers, ensuring effective "organic" farming becomes quite a difficult task.

Under conditions of weather fluctuations, the mobility of macro- and microelements in the soil environment, the rate of plant growth processes, the intensity of photosynthesis and respiration, as well as the activity of biochemical and microbiological reactions that ensure metabolism, change. Accordingly, the development of the root system and the needs of plants for nutrients and the rate of their assimilation are transformed. Therefore, studying the patterns of bioproductivity formation in agrophytocenoses under unstable meteorological conditions is a scientific prerequisite for increasing the sustainability of agricultural systems, especially when farming relies solely on natural soil fertility and is focused on obtaining organic plant products.

In addition, plant yield is determined by how well the conditions of lighting and nutrient supply are coordinated. The temperature regime determines the accumulation of mobile nutrients in the soil. Temperature affects the rate of movement of water and soluble salts and thus influences the rate at which nutrients are supplied to plants from the soil and fertilizers.

The degree of soil moisture significantly determines the availability of nutrients and the efficiency of their assimilation by plants. In conditions of severe moisture deficiency, even sufficient reserves of macro- and microelements do not provide a positive result and can sometimes negatively affect crop formation. Excessive moisture, in turn, disrupts the optimal water-air regime of the soil, inhibits nitrification processes, reduces the supply of nutrients to plants, and contributes to the accumulation of toxic compounds. Thus, at optimal moisture content, the nitrogen assimilation coefficient from fertilizers reaches about 57 %, while at excess moisture it decreases to about 9 %.

Numerous scientific studies prove that the impact of weather and climatic conditions on agricultural results does not weaken over time, but, on the contrary, becomes more pronounced. This is manifested in a wider range of yield fluctuations relative to the average level and an increase in the difference between the most favorable and least productive years. This trend is explained primarily by the fact that modern high-yielding varieties and hybrids, characterized by intensive metabolism and high rates of energy processes, are much more sensitive to changes in the environment. They are more sensitive to any disturbances in water, heat, or nutrient regimes, which leads to increased yield variability [19–21].

In the context of rapid climate change, it is necessary to search for trends that occur over a long series of yield data in terms of the impact of variable hydrothermal indicators on crop productivity in the pre-sowing period and at different stages of the organogenesis of field crops. These data are obtained from the information base of stationary agrotechnical and variety testing experiments, as well as (or) using statistical information at the level of a separate agricultural territory and a network of regional weather stations.

From the point of view of increasing crop yields at low costs of chemical and technogenic resources and justifying measures to adjust the conditions for plant growth and development, it will be relevant to identify the decisive factors and optimal parameters of heat and moisture supply during key periods before and during their vegetation at the local territorial level. On the other hand, an important advantage of this approach is the ability to predict with a high degree of reliability not only crop productivity, but also the functioning of other components of agroecosystems under variable hydrothermal conditions.

The purpose of the study is to develop a methodology for determining critical periods of crop growth depending on hydrothermal conditions; to propose new approaches to predictive modeling of crop productivity, taking into account heat and moisture supply at the stages of organogenesis; to justify the feasibility of further research in this direction.

Materials and methods of research. For modeling, we used the information base of a stationary experiment of the Department of Agriculture and Herbology named after O.M. Mozeyko Department of Agriculture and Herbology of the State Biotechnological University, where 16 variants of field crop rotations with different predecessors of winter wheat were studied over 20 years (1996–2015): clean fallow, peas, vetch, lentils, beans, vetch-oat mixture, soybeans, and corn. The first (No. 1–8) and second (No. 9–16) groups of crop rotations differ in the third crop: sugar beets or buckwheat with the same final fourth crop of spring barley.

The soil of the stationary experiment is typical deep black soil with low humus content and heavy loam on loamy loam with a humus content of 4.94–5.21 %, easily hydrolyzed nitrogen according to Kornfield – 80–130, mobile phosphorus and exchangeable potassium according to Chirikov – 100–150 and 100–200 mg per 1 kg of soil, respectively, pH of water – 7.0, salt – 5.2–5.6.

The area of the sowing plot was 142 m² and the accounting plot was 100 m². An organic farming system was used, with only by-products of the harvest being used as fertilizer: cereal straw and sugar beet tops. The methods described in [22] were used when setting up and conducting the field stationary experiment.

Research results **and discussion.** To assess the impact of air temperature and precipitation on crop productivity, we used ten-day indicators during their cultivation, as well as before and after the growing season. In addition, a sharp reduction in water supply during the growing season is confirmed by the analysis of the Selianinov hydrothermal coefficient. Thus, in the period 1996–2005, the average HTC indicators for April–September fluctuated between 1.0 and 1.2, which, according to the generally accepted scale, corresponds to conditions of weak moisture. However, in recent years, this indicator has fallen below 0.7, indicating a noticeable drought stress. For example, for winter wheat, the period from September of the previous year to July of the following year was assessed. For early spring cereals and fodder crops, the period was from January to July, and for late crops, from January to September. First, the most contrasting yields of each of the crops studied over three or four years were compared, from the lowest to the highest. For example, we selected the following levels of winter wheat grain yield when growing the crop after peas: low yield in 2000 – 1.69 t/ha, average yield in 2015 – 3.21 t/ha, increased yield in 2014 – 4.82 t/ha, and high – yield in 2005 – 6.04 t/ha. Then, graphs of the ten-day dynamics of temperature and precipitation were constructed for the above-mentioned crop periods. This made it possible to establish the difference or deviation of hydrothermal indicators in more favorable and less favorable years in terms of yield. The most productive years in the first ten days of September were significantly cooler than in less productive years (Fig. 1). That is, the temperature regime clearly influenced crop yield before sowing (Fig. 2).

Further on in the period of crop growth and development, it is difficult to assess the difference in heat supply conditions based on ten-day indicators due to their significant fluctuations. This figure only shows that harvest years differ significantly at the end of October and November, and in certain ten-day periods of the winter months. Therefore, based on these data for contrasting years, sixth-order polynomial trend lines were constructed to identify general patterns and deviations. Figure 3 shows that years with different wheat yields differ significantly in terms of average ten-day air temperature from October to March. This means that with an increase in the average daily temperature during the specified period from 15 to 20 °C, grain yield will most likely decrease from 4–6 to 1–2 t/ha.

Based on the preliminary study, a more detailed analysis of the relationship between crop yield and thermal regime in the identified critical periods was conducted: the first ten days of September and October–March. For this purpose, the corresponding twenty-year data series were compared with the construction of first-order polynomial dependencies. It was found that when the average daily air temperature in the first ten days of September rises above 16 °C, there is a tendency for winter wheat grain yield to decrease from 4.5 t/ha. (Fig. 3) This is probably due to the deterioration of moisture supply to crops as a result of increased evaporation and transpiration.

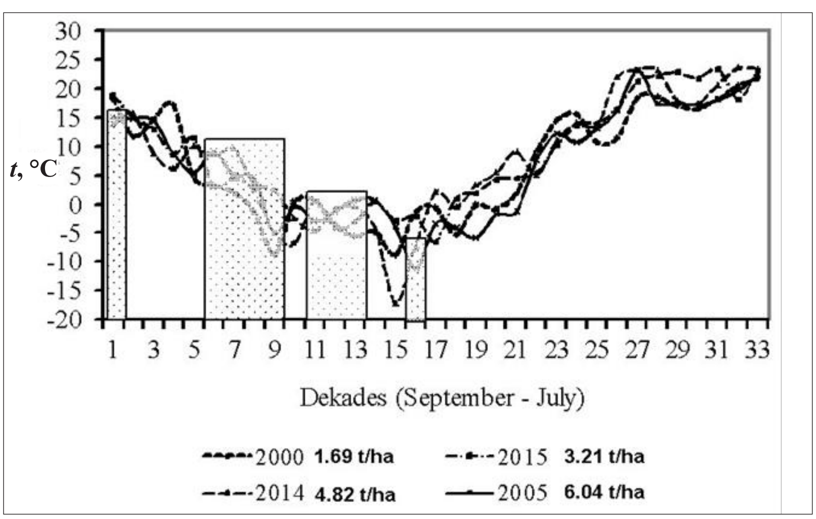

Fig. 1. Decadal dynamics of air temperature in years with different winter wheat yields

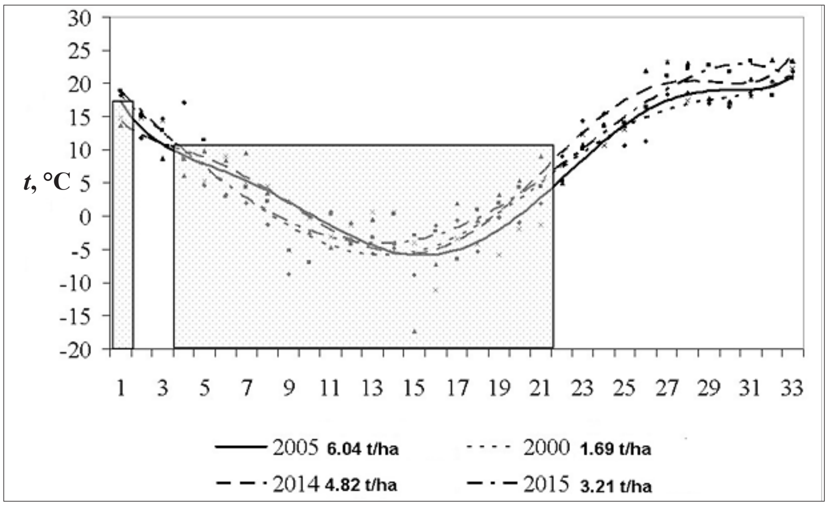

Fig. 2. Trends (6th order polynomials) in the ten-day dynamics of air temperature in different winter wheat yield years

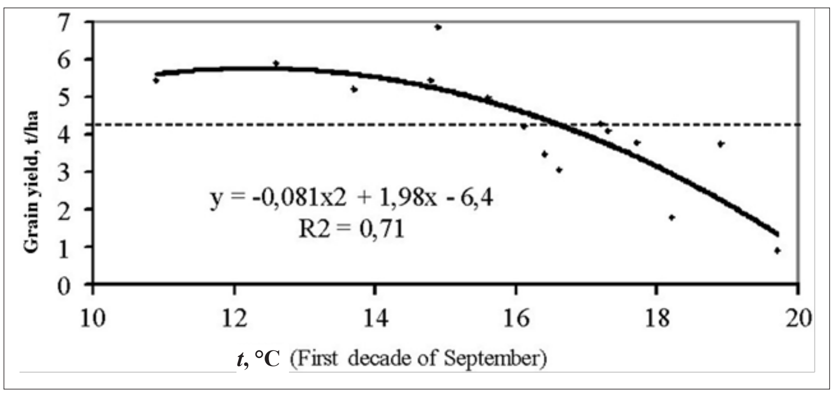

Fig. 3. Dependence of winter wheat yield on the average daily air temperature in the first ten days of September

The relationship between heat supply during the period from October to March and crop yield is shown in Figure 4. It is evident that with an increase in the average daily air temperature during this period above minus 2 degrees Celsius, there is a tendency for the productivity of winter wheat crops to increase from 3 t/ha of grain. In other words, the warmer the wintering period, the more favorable the conditions for grain yield formation.

Figure 5 shows the dynamics of precipitation from September to July in years with different crop yields. As with the temperature regime, the overall state of moisture supply can be represented in a more generalized form using sixth-order polynomial dependencies based on decadal data. Figure 5 shows that more productive years are characterized by higher precipitation in autumn, lower in winter and spring, and higher in summer.

However, a more thorough search for the relationship between moisture supply and crop yield over 20 years of data showed a tendency for crop productivity to increase when the amount of precipitation from the second ten days of September to the first ten days of June was less than 360 mm. Under such conditions, the wheat grain yield will most likely exceed 4.0 t/ha (Fig. 6). However, with a decrease in precipitation during the specified period to 200 mm, a downward trend in grain yield can be observed. There is also the possibility of achieving higher wheat yields when the crops receive 50 to 110 mm of moisture during the period from the third decade of June to the second decade of July.

A decrease or increase in this amount is likely to be accompanied by a grain yield of less than 5 t/ha (Fig. 7). In the first case, this is due to insufficient water supply at the final stage of organogenesis.

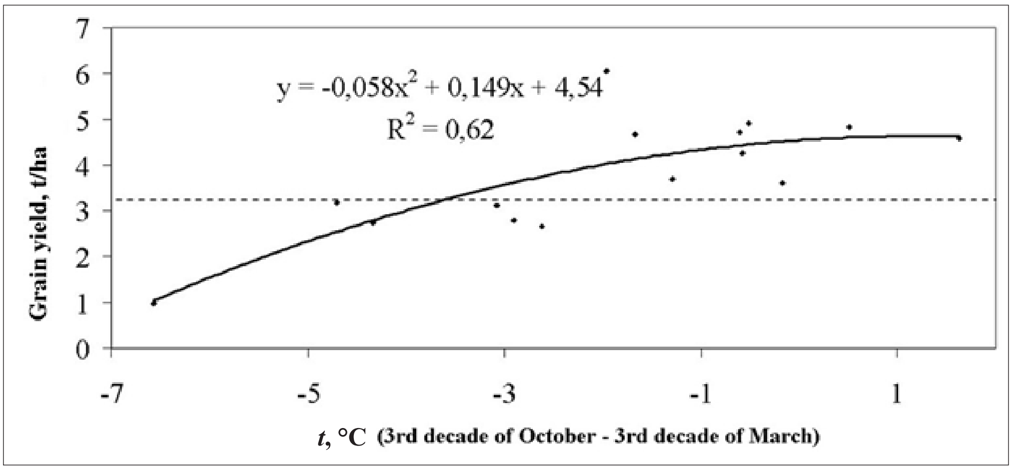

Fig. 4. Dependence of winter wheat yield on the average daily air temperature from the third decade of October to the third decade of March

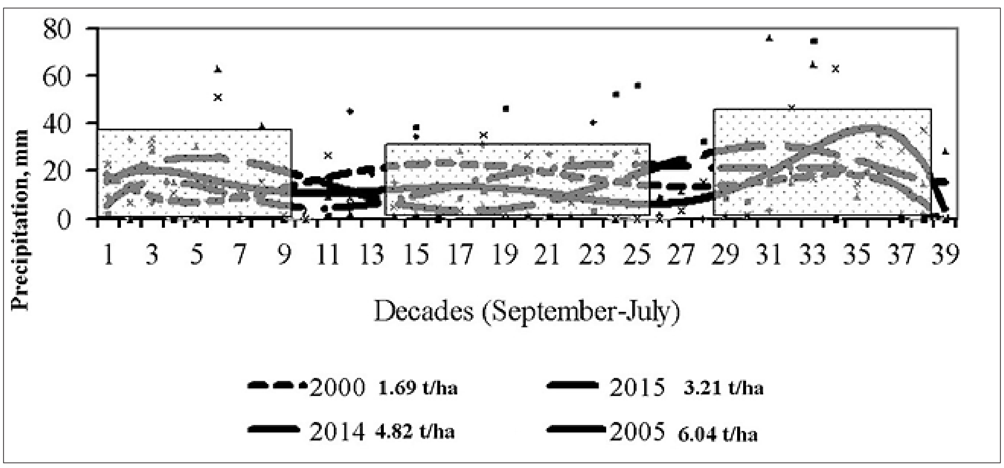

Fig. 5. Trends (6th order polynomials) in the ten-day dynamics of precipitation in different winter wheat yields

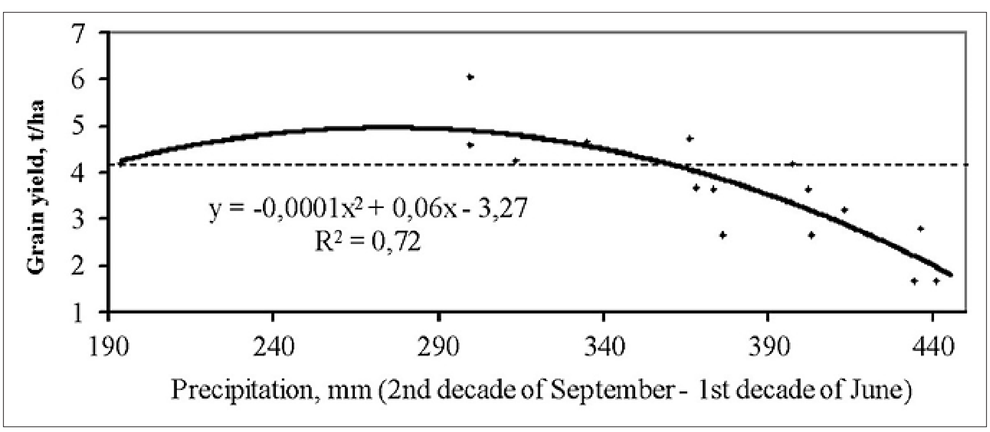

Fig. 6. The dependence of winter wheat yield on the amount of precipitation from the second ten days of September to the first ten days of June

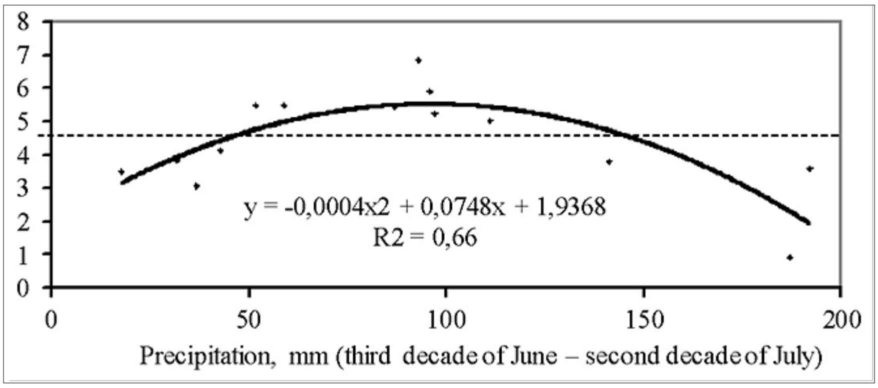

Fig. 7. Dependence of winter wheat yield on the amount of precipitation from the third decade of June to the second decade of July

In the second case, the decline in crop productivity may be associated with more intensive development of harmful organisms or increased grain losses as a result of waterlogging before harvesting. It is also necessary to pay attention to the possible influence of precipitation at the beginning of winter wheat vegetation on its yield. Figure 8 shows that in the case of atmospheric moisture supply during September within the range of 30–70 mm, in many cases the grain yield will exceed 4 t/ha. Lower moisture levels during this period can reduce crop productivity due to insufficient plant development before the winter cold. Conversely, waterlogging leads to a high risk of increased development of harmful organisms, disruption of technological processes, and the impact of other negative factors. Thus, years with different winter wheat yields differ significantly in terms of hydrothermal conditions at certain stages of its organogenesis. Higher crop productivity may be associated with cooler air temperatures in early September and natural moisture supply during this month within the range of 30–70 mm.

A higher crop yield is most likely to be achieved under conditions of higher temperatures during the cold season and moisture supply from September to April not exceeding 350 mm. At the end of the growing season (third decade of June – second decade of July), the desired amount of precipitation is within the range of 50–110 mm. Using the methodology presented in the example of winter wheat, predictive models were developed for the probable impact of hydrothermal conditions on the yield of other field crops at different stages of their organogenesis (Table 1).

When growing sugar beets, there is a tendency for their yield to increase above 30 t/ha when the average daily temperature exceeds 0°C from the third decade of February to the second decade of March (Fig. 9). That is, the warmer it is in the pre-sowing period, the more favorable the conditions for plant growth and development in the future. This is obviously due to faster soil warming in April, the possibility of earlier sowing, reducing unproductive moisture losses due to evaporation, and extending the growing season.

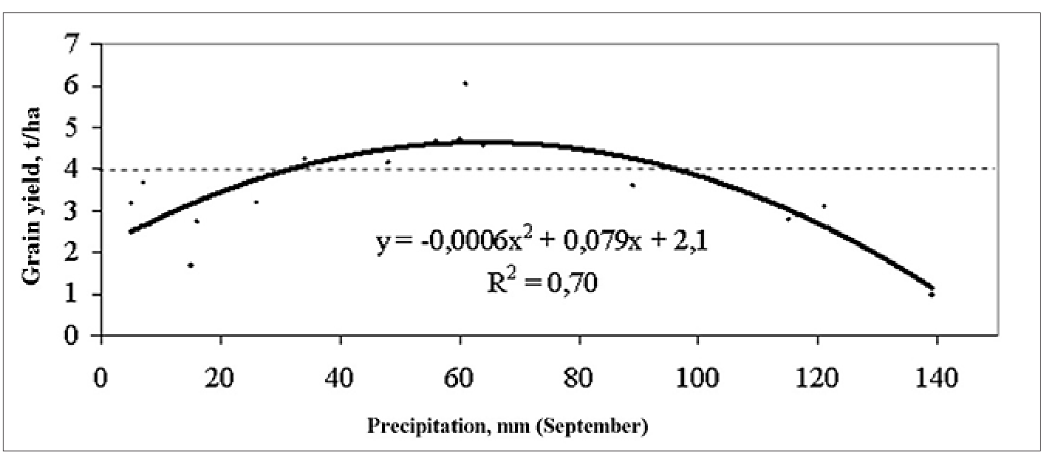

Fig. 8. Dependence of winter wheat yield on the amount of precipitation in September

1. Dependence of crop yields on precipitation and average ten-day air temperature for specific periods of time

Crop	Temperature					Precipitation				
	decade	equation	R^2	°C	t/ha	decade	equation	R^2	mm	t/ha
Winter wheat	September 1	$y = -0.081x^2 + 1.98x - 6.4$	0.71	10	> 4.5	September 1–3	$y = -0.0006x^2 + 0.08x + 2.1$	0.69	30–90	> 4.0
	October 3 – March 3	$y = -0.058x^2 + 0.149x + 4.54$	0.62	−7 – (−2)	< 3.5	September 2 – June 1	$y = -0.0001x^2 + 0.06x - 3.27$	0.72	< 370	> 4.0
Sugar beets	February 3 – March 2	$y = -0.01x^2 + 0.5x + 34$	0.62	> 0	> 32	May 3	$y = -0.0033x^2 + 0.6x + 17.5$	0.57	> 20	>28
	April 3 – May 2	$y = 0.339x^{2-}12.2x + 132$	0.56	< 14	>28	August 1 – September 3	$y = 3E - 05x^2 - 0.2x + 43.9$	0.66	< 70	>28
Buckwheat	April 2 – May 1	$y = -0.035x^2 + 0.955x - 5.06$	0.59	< 11 >14	< 1.3	July 3 – September 1	$y = -0.0001x^2 + 0.0255x + 0.35$	0.65	90–100	> 1.4
	June 2	$y = 0.035x^2 - 1.54x + 18$	0.69	< 20	> 1.3	–	–	–	–	–
	August 2-3	$y = -0.062x^2 + 2.52x - 24$	0.71	>23	< 1.0	–	–	–	–	–
Barley after beet	May 1 – June 3	$y = 0.0063x^2 - 0.51x + 9.47$	0.59	< 17	> 2.7	May 3 June 2	$y = -0.0009x^2 + 0.13x - 1.66$	0.66	50–90	> 2.5
	–	–	–	–	–	January 3 – March 2	$y = 0.0006x^2 - 0.074x + 4.0$	0.53	> 90	> 2.5
Barley after buckwheat	May 1 – June 3	$y = 0.052x^2 - 2.24x + 25.3$	0.66	< 17	> 2.5	January 3 – April 3	$y = 0.0001x^2 - 0.0115x + 1.48$	0.67	> 150	> 2.0
Peas	April 3 – May 2	$y = 0.05x^{2-}1.71x + 15.8$	0.61	< 13	> 2.5	June 2-3	$y = -0.0007x^2 + 0.08x + 0.36$	0.7	25–85	> 2.2
Vetch-oat mix	June 3 – July 1	$y = -0.27x^2 + 22.1x - 430$	0.63	38	> 18	April 1 – June 3	$y = 8E - 05x^2 + 0.033x + 6.8$	0.66	> 210	> 17
Corn MWR	March 2 – April 1	$y = 0.09x^2 - 1.124x + 18.7$	0.67	> 6	> 30	April 2 May 1	$y = 0.005x^2 - 0.2x + 20$	0.77	> 50	> 25
	July 2 – August 3	$y = 2.17x^2 - 89.4x + 936$	0.74	> 22	> 23	June 1 July 1	$y = -0.001x^2 + 0.39x - 0.63$	0.62	> 80	> 25

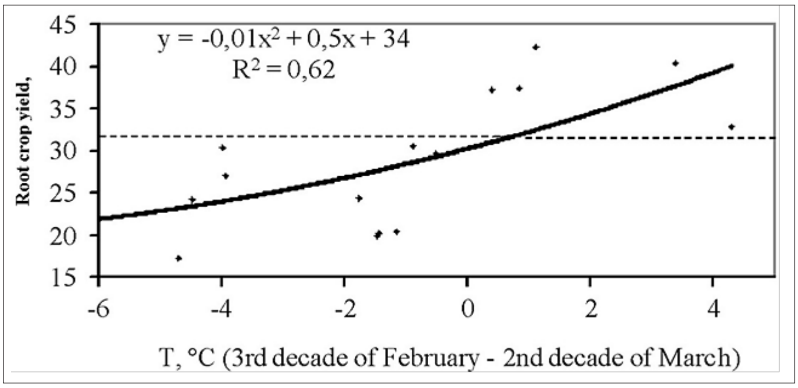

Fig. 9. Dependence of sugar beet yield on average daily air temperature from the third decade of February to the second decade of March

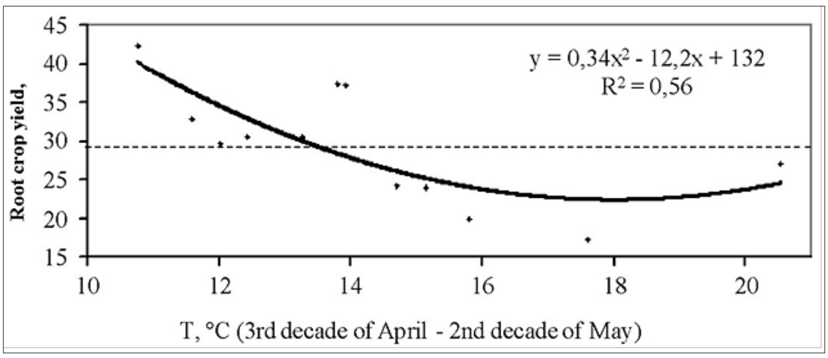

Fig. 10. Dependence of sugar beet yield on average daily air temperature from the third decade of April to the second decade of May

It should also be noted that there is a high probability of reduced crop productivity under increased heat conditions during the spring months of vegetation for this crop (Fig. 10). Thus, if the average daily air temperature from the third decade of April to the second decade of May exceeds 14 °C, the root crop yield will not exceed 30 t/ha. In terms of heat supply, mid-summer can be of great importance. Thus, Figure 11 shows the possibility of an increase in sugar beet yield from 25 t/ha if the average temperature in the first ten days of July is below 20 or above 24 °C (Fig. 11). This situation can be explained by the influence of factors other than thermal conditions, in particular the specifics of the development of harmful organisms.

During the period of active growth of sugar beet foliage, moisture conditions are particularly important. In this case, there is a tendency for root crop yields to exceed 30 t/ha when precipitation in the third ten days of May exceeds 20 mm (Fig. 12).

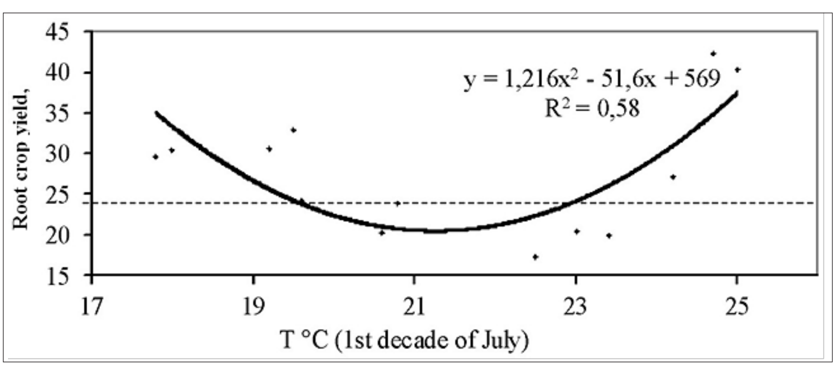

Fig. 11. Dependence of sugar beet yield on the average daily air temperature in the first ten days of July

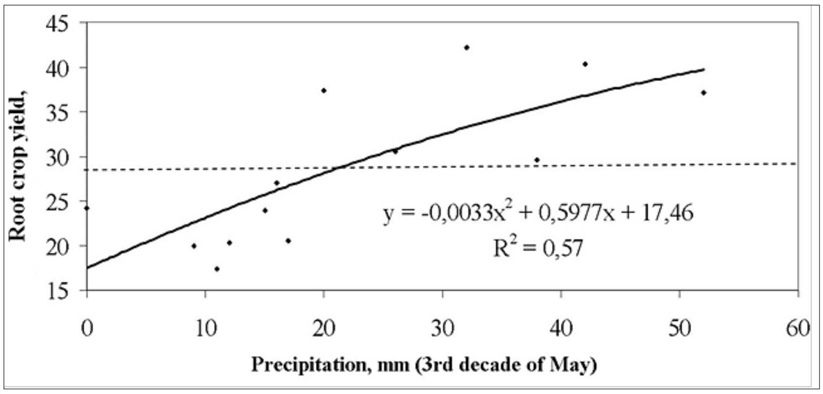

Fig. 12. Dependence of sugar beet yield on precipitation in the third ten days of May

It is highly probable that crop productivity will decrease from 30 t/ha when the amount of precipitation for the period August–September exceeds 70 mm. This can be explained by the more active development of harmful vegetation (weeds), difficulties in harvesting, and the influence of other factors (Fig. 13).

Comparison of the dynamics of ten-day air temperature in more productive buckwheat years (2001, 1.5 t/ha, and 2005, 1.85 t/ha) and in less productive years (2002, 0.8 t/ha, and 2006, 0.7 t/ha) yields (2007, 0.72 t/ha, and 2003, 1.1 t/ha) showed noticeable differences from late April to early May, in June, and in August. Indeed, with an increase in the average daily temperature in the period from the second ten days of April to the first ten days of May above 11°C, there is a tendency for the yield of this crop to increase from 1.2 t/ha to a maximum of 1.5–1.8 t/ha at 12°C (Fig. 14).

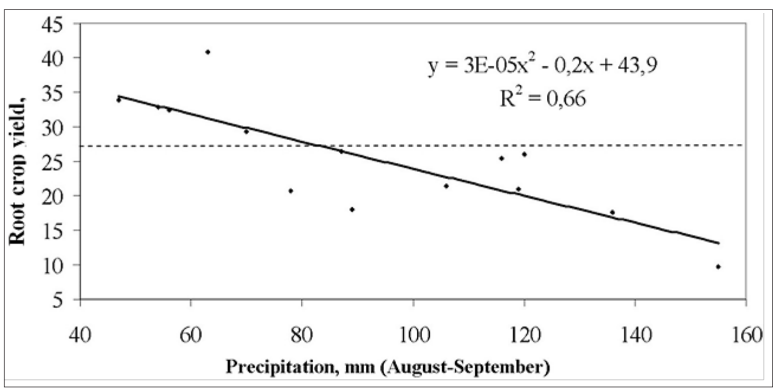

Fig. 13. Dependence of sugar beet yield on the amount of precipitation from the first ten days of August to the third ten days of September

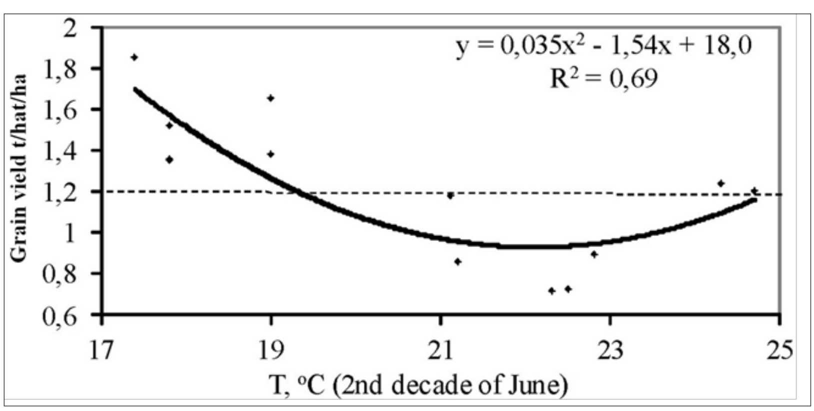

Fig. 14. Dependence of buckwheat yield on the average daily air temperature in the second ten days of June

There is also a correlation between thermal conditions in the second ten days of June and buckwheat crop productivity. Thus, if the average temperature during this period does not exceed 19 °C, a grain yield of more than 1.3 t/ha can be expected. The level of heat supply can also affect the condition of crops at the end of summer. In particular, if the average temperature for the second and third decades of August exceeds 23 °C, the risks of a decrease in buckwheat productivity from the level of 1 t/ha increase.

In terms of maximum precipitation, the most productive year, 2005 (1.85 t/ha), differs from the others in the second ten days of March, the first and second ten days of June, the first ten days of July, and the second ten days of August (Fig. 15). If we take the total amount of moisture that fell on the crops during these decades, then over a 15-year period it will correlate quite closely with grain yield (R^2=0.76). Moreover, if the total precipitation during these periods is less than 50 mm, the risk of a decrease in yield from the level of 1 t/ha increases (Fig. 16). The impact of moisture supply in the second half of summer and early autumn on buckwheat crops may also be specific. With a 65 % probability, yields above 1.5 t/ha can be achieved provided that between the third decade of July and the first decade of September, there is no less and no more than 95–105 mm of atmospheric moisture. The risk of crop failure (<1.2 t/ha) increases during harvesting (first and second decades of September) if the amount of precipitation exceeds 25 mm.

In general, spring barley reacted weakly to changes in hydrothermal conditions over the years. This is probably due to the short growing season and the rapid use of available heat and water resources before the crop matures. However, the yield of spring barley after sugar beets may depend on the average daily air temperature from May to June. If this indicator exceeds 13 °C, it is difficult to expect a crop yield higher than 2.7 t/ha. There is also a certain dependence of the yield of barley grain after sugar beets on the amount of precipitation from the third decade of May to the second decade of June. When 50 to 80 mm of precipitation falls during this period, the probability of obtaining a grain yield above 2.5 t/ha increases significantly.

The growth and development of spring barley sown after buckwheat was also influenced by the average ten-day temperature regime in May–June, with yields increasing from 2.5 t/ha when the average air temperature did not exceed 17° C. At the same time, in the absence of precipitation in the third decade of April, one should not expect crop productivity to exceed 2.0 t/ha.

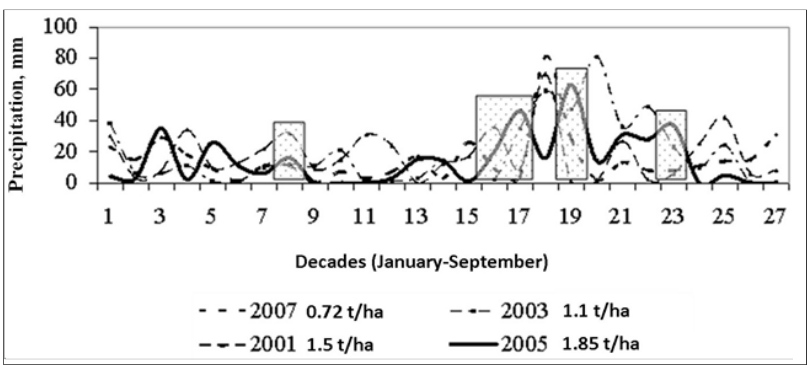

Fig. 15. Ten-day dynamics of precipitation in years with different buckwheat yields

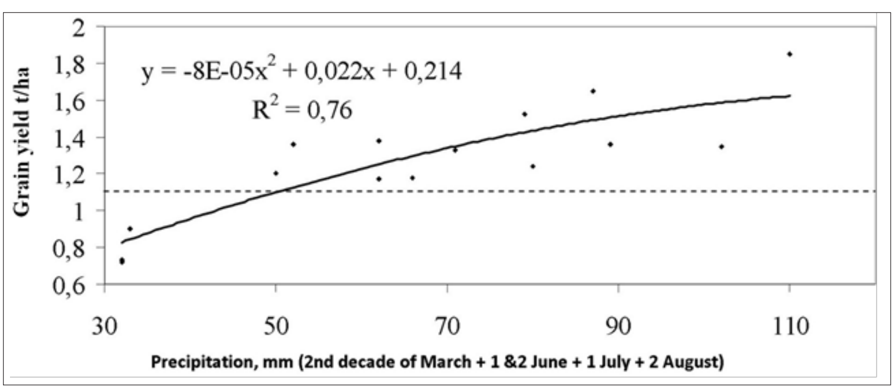

Fig. 16. Relationship between precipitation in the second ten days of March, the first and second ten days of June, the first ten days of July, and the second ten days of August and buckwheat yield

A comparison of the dynamics of different years in terms of pea yield showed that the most favorable year, 2008, differed significantly from the unfavorable year, 2014, in terms of temperature regime in almost all decades from April to July. A more thorough analysis of long-term yield and temperature series showed that at the beginning of the growing season, peas can suffer from increased heat. The figure shows that when the average daily air temperature rises above 15 °C from the third decade of April to the second decade of May, the crop's productivity potential is limited to 1.2–1.3 t/ha.

From late spring to the end of the growing season, the impact of temperature conditions can be specific. If from the third decade of May to the second decade of July this indicator is less than 18 °C or more than 22 °C, a tendency towards a significant reduction in grain yield can be observed. A lack of heat creates unfavorable conditions for plant growth and development, while hot weather causes premature ripening of the crop (Figs. 17–18). That is, a pea yield above 1.5 t/ha can be expected when the average air temperature in the first half of the growing season is above 15 °C and in the second half is in the range of 18–22 °C.

A comparison of moisture supply dynamics in favorable and unfavorable years showed that in more productive years, there was significantly less precipitation in June. A comparative analysis of long series of relevant indicators showed that atmospheric moisture affects pea productivity in the second and third decades of June. The amount of precipitation during these decades should be no less than 25 mm and no more than 85 mm (Fig. 19). In this case, a grain yield of at least 2 t/ha can be expected, with a maximum value of 3.2 t/ha for 75 mm of precipitation on crops.

The probability of obtaining a green mass yield of annual grasses (vetch-oat mix) of more than 18 t/ha will significantly decrease if the average daily air temperature is less than 19 °C and more than 21 °C during the period from the third decade of June to the first decade of July (pre-harvest period). The same effect (>18 t/ha of green mass) can be expected if the amount of precipitation in April–June exceeds 200 mm, with a maximum level of 25 t/ha at a moisture level of 300 mm.

Soybeans grown for green mass respond well to higher temperatures in the pre-sowing period, which is probably due to earlier soil "maturation" and a longer growing season. Thus, if this indicator exceeds 5 °C in the third decade of March, the possibility of obtaining more than 17 t/ha of green mass increases significantly, with a maximum level of 22 t/ha at 9 °C.

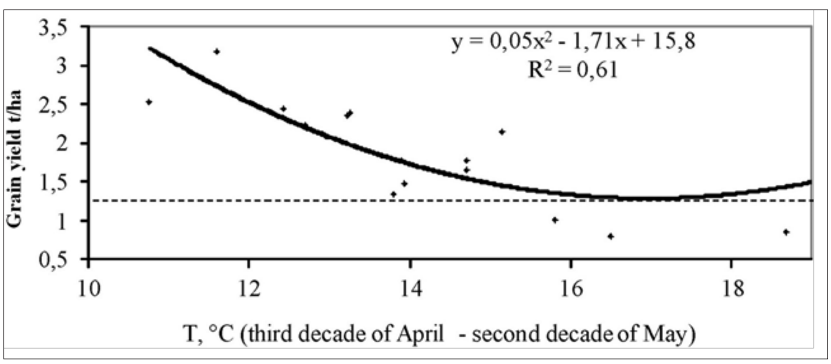

Fig. 17. Relationship between the average daily air temperature from the third decade of April to the second decade of May and pea yield

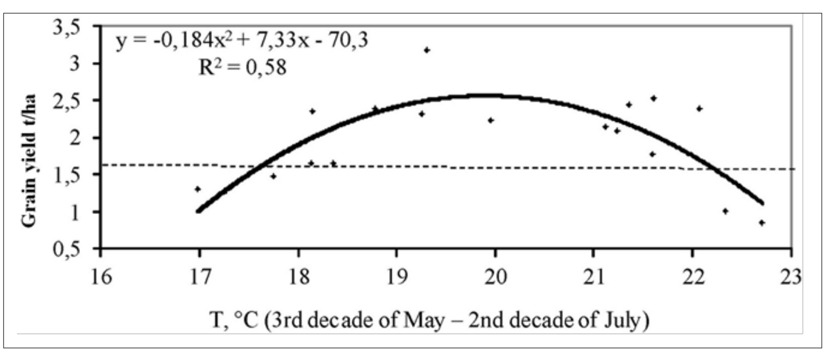

Fig. 18. Relationship between the average daily air temperature from the third decade of May to the second decade of July and the yield of peas

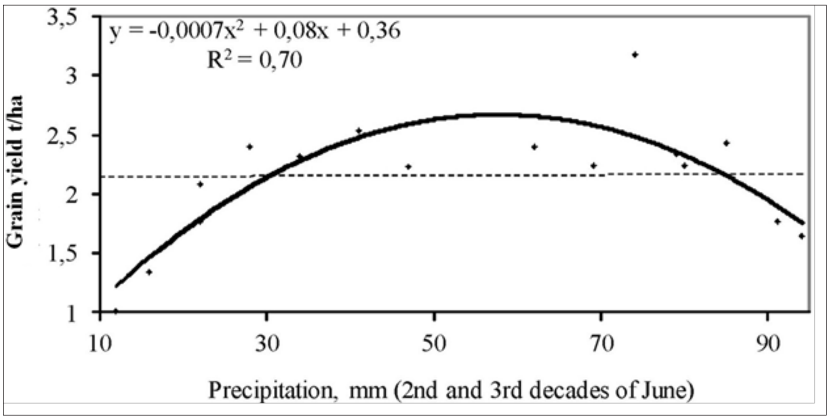

Fig. 19. Relationship between precipitation in the second and third decades of June and pea yield

For soybeans, the amount of precipitation can be important in the pre-sowing and pre-harvest stages. Thus, if more than 60 mm of moisture falls between the second ten days of February and the first ten days of April, the probability of a decrease in green mass yield from the level of 15 t/ha increases significantly. In summer (June–second ten days of July), if moisture intake does not exceed 110 mm or increases from 190 mm, a drop in green mass yield below 17 t/ha can be expected.

To preliminarily establish the impact of hydrothermal conditions in the pre-sowing period and directly during the growing season of corn for silage, the ten-day dynamics of these conditions were compared in years with different yields: 1999 – 13 t/ha, 2012 – 23 t/ha, 2007 – 32 t/ha, 2008 – 43 t/ha. It was found that the air temperature in years with different productivity differed most significantly in March and in the summer months. A comparison of long series of yield data and thermal indicators showed that corn yield can increase significantly (>30 t/ha) when the average daily temperature from the second ten days of March to the first ten days of April exceeds 6º C. Similar results were obtained from the analysis of data on heat-loving soybeans. If the heat supply to crops from the second ten days of July to the third ten days of August exceeds 22 °C, the probability of obtaining more than 25 t/ha of green mass increases significantly, with a maximum level of 36 t/ha as the temperature approaches 24 °C.

A comparative assessment of the dynamics of decadal precipitation in years with different yields showed significant variation in this indicator in the period from January to September. A significant advantage of a productive year in terms of moisture content can be noted in April and in the first half of summer. A more thorough search for dependencies showed that with an increase in precipitation from the second ten days of April to the first ten days of May from a level of 50 mm, a green mass yield of more than 25 t/ha can be expected, with a maximum level of 43 t/ha for 90 mm of precipitation. A prerequisite for obtaining more than 25 t/ha of silage mass may be precipitation of at least 80 mm from the first ten days of June to the first ten days of July.

Conclusions.

A methodological approach to establishing critical periods for the formation of field crop yields is proposed, based on the analysis of long-term (15–20 years) series of statistical data on yields and corresponding ten-day indicators of air temperature and precipitation at the local territorial level. The methodology involves a two-stage procedure: first, the construction of graphs of the dynamics of hydrothermal indicators in years with contrasting productivity to identify periods of the most pronounced deviations; at the next stage, a detailed correlation analysis of the dependence of yield on weather conditions in the identified critical periods.

Key periods of vegetation have been established when the dependence between hydrothermal conditions and field crop yields manifests itself with a sufficient level of reliability. The obtained polynomial regression models allow predicting crop productivity depending on the temperature regime and moisture supply at critical stages of organogenesis in the conditions of the Left-Bank Forest-Steppe of Ukraine.

Limitations in the reliability of the developed models have been identified, caused by the failure to take into account a complex of related factors of the bioproductivity of agrophytocenoses, namely: the duration of individual stages of organogenesis, the dynamics of the soil nutrient regime, its agrophysical properties, the phytosanitary condition of crops, the impact of extreme weather events, etc. Further improvement of predictive models requires multifactorial analysis with simultaneous monitoring of crop yields, hydrothermal conditions, and other agroecological parameters, which will increase the accuracy and practical value of crop productivity forecasting in the context of climate change.

Conflicts of interest: the authors declare no conflict of interest.

Use of artificial intelligence: the authors confirm that they did not use artificial intelligence technologies during the creation of this work.

References

1. Kernasyuk, Yu.V. (2021). The global climate crisis and its impact on the development of Ukraine's agricultural sector. Economy of AIC, (9), 91–101.
2. Barabash, M.B., Tatarchuk, O.G., Grebenyuk, N. P., & Korzh, T.V. (2012). The impact of climate change on agricultural production. Economy of AIC, (10), 33–37.
3. Heino, M., Guillaume, J.H.A., Muller, C., et al. (2020). A multi-model analysis of teleconnected crop yield variability in a range of cropping systems. Earth System Dynamics, 11 (1), 113–128. DOI: https://10.5194/esd-11-113-2020
4. Anderson, W. B., Seager, R., Baethgen, W. (2019). Synchronous crop failures and climate-forced production variability. Science Advances, 5 (7), eaaw1976. DOI: https://doi.org/10.1126/sciadv.aaw1976
5. Challinor, A.J., Watson, J., Lobell, D.B. (2014). A meta-analysis of crop yield under climate change and adaptation. Nature Climate Change, 4 (4), 287–291. DOI: https://doi.org/10.1038/NCLIMATE 2153
6. Palshuk, N.S. (2015). Formation of grain productivity of winter wheat depending on the variety, predecessor, and mineral nutrition in the northern steppe of Ukraine (Doctoral dissertation). Institute of Agriculture of the Steppe Zone of the National Academy of Agrarian Sciences, Dnipropetrovsk.
7. Kaminsky, V.F., & Saiko, V.F. (2015). Agriculture in the 21st century. Problems and solutions. Agriculture, (2), 3–11.
8. Romashchenko, M.I., & Tarariko, Yu.O. (Eds.). (2017). Reclaimed agroecosystems: Assessment and rational use of Ukraine's agricultural resource potential (irrigation and drainage zones). Kyiv; Nizhyn: Publishing House PP Lysenko M.M.
9. North-Eurasian Climate Center. (2016). Review of the state of climate change for 2016 (January–December). Retrieved from: https://www.necc.org/en/
10. Lai, L., Kumar, S., Chintala, R., Owens, V.N., Clay, D., Schumacher, J., Nizami, A.S., Lee, S. S., & Rafique, R. (2016). Modeling the impacts of temperature and precipitation changes on soil CO_2 fluxes from a switchgrass stand recently converted from cropland. Journal of Environmental Sciences, 43, 15–25.
11. Blyzniuk, B.V., Los, R.M., Demidov, O.A., Kirilenko, V.V., Gumenyuk, O.V., & Danyuk, T.A. (2019). The influence of weather conditions on the duration of individual vegetation periods and the yield of soft winter wheat in the Forest-Steppe and Polissya regions. Myronivsky Visnyk, (8), 73–90.
12. Lapchynskyi, V.V., Lakusta, A.A., & Khmeliantchyshyn, Yu.V. (2024). The impact of climate change on agronomy: assessment and adaptation measures. Tavriia Scientific Bulletin, 137, 516–524. https://doi.org/10.32782/2226-0099.2024.137.60
13. Gadzalo, Y.M., Vozhegova, R.A., Kokovikhin, S.V., et al. (2020). Scientific justification of corn cultivation technologies on irrigated lands, taking into account hydrothermal factors and climate change. Irrigated agriculture, 1 (73), 21–26. DOI: https://doi.org/10.32848/0135-2369.2020.73.3
14. Kryvohyzha, E.M., Matviishyn, A.I., & Bryn, V.T. (2024). The impact of climate change on the yield of major crops in Ukraine. Podilskyi Visnyk: Agriculture, Technology, Economics, 3 (44), 33–37. https://doi.org/10.37406/2706-9052-2024-3.5
15. Shkurko, V.S. (2011). The impact of weather conditions on the yield of spring barley and the possibility of forecasting yields. Bulletin of the Poltava State Agrarian Academy, 4, 156–159.
16. Stationary field experiments in Ukraine. Register of certificates. (2014). Kyiv: Agrarian Science.
17. Kulik, M.I., & Rozhko, I.I. (2017). The influence of weather conditions during the growing season on the productivity and yield of broomcorn millet. Bulletin of the Poltava State Agrarian Academy, 4, 50–55.

18. Romashchenko, M.I., Vozhegova, R.A., & Shatkovsky, A.P. (Eds.). (2017). Scientific foundations for the development of the agricultural sector of the southern region of Ukraine. Kherson: OLDI-PLUS.

19. Holzkamper, A., Calanca, P., & Fuhrer, J. (2013). Identifying climatic limitations to grain maize yield potentials using a suitability evaluation approach. Agricultural and Forest Meteorology, 168, 149–159. DOI: https://10.1016/j.agrformet.2012.09.004

20. Mialkovsky, R.O. (2018). The influence of meteorological factors on potato yield in the conditions of the Right-Bank Forest-Steppe. Agriculture: interdepartmental thematic scientific collection, 1 (94), 55–61.

21. Mishchenko, Yu.G., Prasol, V.I., Davydenko, G.A., Masik, I.M., Ermantraut, E.R., & Gudz, V.P. (2024). Methods of scientific research in agronomy: textbook. Sumy: SNAU. https://repo.snau.edu.ua/bitstream/123456789/13336/1/2024_Посібник_Методика%20наукових%20досліджень%20в%20агрономії.pdf

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ВПЛИВ ЗМІННИХ ПОГОДНИХ УМОВ НА ВРОЖАЙНІСТЬ ПОЛЬОВИХ КУЛЬТУР У ЛІВОБЕРЕЖНОМУ ЛІСОСТЕПУ УКРАЇНИ

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Анотація. *За різних погодних умов змінюються темпи розвитку рослин, рухомість елементів живлення у ґрунті, інтенсивність фотосинтезу та активність ґрунтової біоти. Оптимізація водно-повітряного і поживного режимів ґрунту через меліорації дає змогу значною мірою нівелювати негативну дію несприятливих погодних умов та підвищити сталість продуктивності агрофітоценозів. Однак в умовах «органічного» землеробства у регіонах з дефіцитом зволоження без достатніх водних ресурсів і мінеральних добрив ефективне аграрне виробництво є проблематичним. Встановлення закономірностей впливу умов зволоження і теплозабезпечення на окремих етапах органогенезу є теоретичною основою підвищення сталості землеробства, зокрема за використання лише природної родючості ґрунту та побічної біомаси. Метою роботи було встановлення закономірностей змін врожайності польових культур у різних сівозмінах залежно від динаміки агрометеорологічних факторів в умовах недостатнього зволоження східного Лісостепу України та оцінка потенціалу продуктивності посівів з урахуванням щорічно змінних гідротермічних умов у системі «органічного» землеробства без застосування мінеральних добрив. Оцінку змін агрометеорологічних ресурсів здійснювали методом математико-статистичного аналізу подекадних показників теплозабезпечення (температури повітря та опадів) і врожайності польових культур. Дані 20-річного стаціонарного досліду оброблялися методами кореляційного та розрахунково-порівняльного аналізу із системним узагальненням. Встановлено найбільш вірогідні ключові періоди до вегетації та під час органогенезу, коли залежності між погодними умовами та врожайністю проявляються з достатнім рівнем достовірності. Запропонований підхід ґрунтується на формуванні статистичних рядів урожайних даних (15–20 років) та відповідних подекадних показників температури і опадів на локальному просторі. Рекомендовано спочатку побудувати графіки динаміки гідротермічних умов у різні за врожайністю роки для виявлення періодів найочевидніших відхилень, а потім провести детальний пошук математичних залежностей продуктивності від погодних умов.*

Ключові слова: *кореляція, гідротермічні умови, польові культури, урожайність, природний фон родючості ґрунту, органічна продукція*