DOI: https://doi.org/10.31073/mivg202302-367
Available at (PDF): https://mivg.iwpim.com.ua/index.php/mivg/article/view/367

UDC: 633.34:631.4

FEATURES OF MAIZE GROWING FOR GRAIN IN THE WESTERN FOREST ZONE OF UKRAINE IN THE CONDITIONS OF CURRENT CLIMATE CHANGES

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Abstract. *Modern climatic changes, namely significant warming in the northern Forest-Steppe and Polissia zones of Ukraine, provide opportunities for the cultivation of a number of grain and leguminous crops (maize for grain, soybeans, sunflower, and others), previously uncharacteristic of this region. Among the above-mentioned crops, corn has the greatest grain yield potential, therefore it is one of the most common crops in world agriculture. If 10–15 years ago corn was not grown for grain in the Polissia zone, then in recent years its sown areas have grown significantly, and the yield in some years is not inferior to the regions of the Forest Steppe and Steppe, which are traditional for this crop. The results of experimental studies of the station showed that under favorable conditions on the most fertile slopes of the drained sod-podzolic soils of the Western Polissia zone, with intensive technologies, it is possible to obtain more than 10–12 t/ha of corn grain.*

The analysis of hydrothermal indicators shows that with the current indicators of heat supply of the growing season in the zone of Western Polissia on mineral soils, it is possible to achieve not only early-ripening, but even medium-early hybrids of corn with FAO up to 280–300. Drained peat soils, due to their high nitrogen content and sufficient amount of moisture, have sufficient potential for obtaining a high yield of corn grain. However, its indicators over the years of research vary greatly and depend to a large extent on the agro-meteorological conditions of the growing season. It has been established that the main limiting factors for achieving a high yield of corn grain on peat soils are less favorable microclimatic features (less amount of active heat, shorter growing season and frost-free period, etc.) compared to adjacent sod-podzolic soils located nearby on dry land. It has been experimentally established that under conditions of minimum duration without a frost period, only the most early-ripening hybrids of corn with FAO up to 220–240 will have time to form a full-fledged crop of grain on drained peat soils in the Western Polissia zone. By choosing late-ripening hybrids, there is a risk of a significant shortfall in the harvest due to the premature termination of vegetation caused by early autumn frosts. It was established that the highest yield of corn per grain, both on sod-podzolic and peat soils, was provided by the organo-mineral fertilization system, which was based on the application of complete mineral fertilizer at the rate of $N_{90}P_{90}K_{90}$ *on turf-podzolic soils and* $N_{35}P_{60}K_{120}$ *on peat soils in combination with phosphorus mobilizing drug Rice Pi. The use of the organo-mineral fertilization system (*$N_{90}P_{90}K_{90}$ *+ phosphorus mobilizing drug Rice Pi) ensured an increase in the yield of corn on sod-podzolic soils by 30.2 ct/ha compared to the basic fertilization system (*$N_{30}P_{30}K_{30}$*). The use of the organo-mineral fertilization system (*$N_{35}P_{60}K_{120}$ *+ phosphorus mobilizing drug Rice Pi) ensured an increase in the yield of corn on peatlands by 56.8 ct/ha compared to the natural background of fertility.*

Key words: *drained lands, corn, varieties and hybrids, zone of Western Polissia, climate changes, fertilization system*

The relevance of research. Corn is one of the most common crops in world agriculture. Its main acreage is concentrated in the USA, Argentina, and Brazil. In the USA, there is a corn belt where it has been grown in monoculture for more than 40 years, and its yield is consistently at least 12–16 t/ha. In addition to the United States, corn monoculture is also practiced in France. Two-field crop rotation is common in the United States, consisting of alternating soybeans and corn. For corn farmers in Canada and the USA, the grain yield standard is 20–25 t/ha [1–3].

The world's highest corn grain yield (total of irrigated and irrigated plantations) is 41.44 t/ha, obtained in 2019 by farmer Dave Hula from Virginia (USA). Hula uses mulching, minimum tillage and irrigation on his farm [1, 4].

On unirrigated fields, the last world record for corn yield was reached in 2002 by Francis Child with a result of 29.73 t/ha. Twenty years later, in 2022, this record was broken by farmer Russell Hendrick from North Carolina (USA). For more than 10 years, Hendrik has been innovating on his 300-hectare farm to improve the properties of his soils. His unirrigated, no-till corn plantation, has reached the 30 t/ha mark. The current yield record is 30.9 t/ha [4]. It is worth noting that the climate of North Carolina is classified as subtropical. The average annual rainfall in this area is about 1100–1300 mm

In Ukraine, irrigation yields 13–15 t/ha of corn grain, in some farms, under favorable conditions, the yield reaches 16 or more t/ha [3–4].

Over the past decade, the corn sown area in Ukraine has increased from 1.9 million hectares in 2007 to 5.3 million hectares in 2021, or more than 2.5 times, and the area of its cultivation has also expanded. It is characteristic that the rate of increase in the average yield of corn per grain in Ukraine is the highest in the world [5]. This is a consequence of the introduction of progressive technologies in its cultivation and the introduction of new highly adapted varieties and hybrids of the world's leading breeding companies.

If 10–15 years ago corn was practically not grown for grain in the Western Polissia zone, recently its sown areas have grown significantly, and the yield in some years is not inferior to the regions of the Forest Steppe and Steppe that are traditional for this crop [2, 4, 6].

There are also examples of corn cultivation in monoculture in Ukraine. In particular, the agricultural company "Zemlya i Volya" in Chernihiv Oblast is a vivid example of successful corn cultivation in monoculture. In recent years, the area under monoculture of corn in this enterprise is about 30.000 hectares, and the yield of grain consistently reaches more than 8–10 t/ha. The technology is based on the plowing of crop residues, the use of trichogram, as well as the introduction of anhydrous ammonia. Periodic analyses of the soil indicate that its quality is gradually increasing due to the constant introduction of organic matter with plant residues. At the same time, there are no outbreaks of diseases or an increase in the number of pests [7].

Studies have proven that the potential yield of corn grain under favorable conditions in the Western Polissia zone can be more than 11–12 or more t/ha, however, to obtain such a yield, many factors and technological nuances specific to this zone should be taken into account [2, 3, 8, 9, 10].

Analysis of recent research and publications. A significant amount of research on the selection of the most highly productive and adapted corn hybrids for the Western Polissia zone, including on drained lands, is being conducted by Zakhidagroprom LLC, which in 2019 launched the Agrarian Polygon project in the village of Yarynivka, located in the north of the Rivne region. The data obtained at the Agrarian Polygon show that the yield of corn grain in the Western Polissia zone significantly depends on the cultivated hybrid, its maturity group and the weather conditions of a particular year. Thus, in 2020, certain hybrids of corn under production conditions ensured a grain yield of more than 14–15 t/ha. It was also established that the difference in productivity between individual hybrids can differ quite significantly [6].

Researches of the Polyssia Institute of Agriculture of the National Academy of Agrarian Sciences of Ukraine have established that among crops, corn has a high yield potential on sod-podzolic soils. Thus, in the conditions of drained soddy-podzolic soils, the highest yield of grain (6.05 t), feed (6.56 t) and feed protein units (5.66) per 1 ha of area was obtained in a three-field crop rotation with 66.6 % corn per combination by-products with an increased rate of mineral fertilizers ($N_63P_{85}K_{90}$).

A decrease in the share of corn to 33.3 % in a three-field crop rotation and to 25 % in a four-field crop rotation under a similar fertilization system led to a decrease in their productivity – to 4.52 and 4.23 tons of grain or 5.44 and 4.52 tons of fodder units, in accordance. Crop rotation without corn reduced harvest by an average of 50 % [11].

It should be noted that most of the studies on the cultivation of corn for grain in the Polissia zone were conducted on sod-podzolic soils and their variations. Regarding the cultivation of corn for grain on drained peat soils, this issue has not been sufficiently studied until recently, as it was grown here mainly as a fodder crop to obtain high-quality silage.

Peat soils naturally have a high supply of nitrogen [9, 10], therefore, in the conditions of a significant increase in the price of nitrogen fertilizers, they can be considered as a significant reserve for expanding the area of corn for grain in the Polissia zone.

The research of the Sarnenska Research Station in recent years shows that with proper phosphorus-potassium nutrition and the correct selection of hybrids on peat soils, it is possible to obtain a high yield of corn grain. However, on peat soils, there are many limiting factors and nuances of technology, and not taking them into account makes it impossible to fully realize the potential of this crop. In particular, peat soils, compared to adjacent mineral soils located on dry land, have specific water-physical and microclimatic features. Here, the vegetation and frost-free period is much shorter, which greatly complicates the corn's cultivation [13].

Therefore, the issue of growing corn for grain in the Western Polissia zone has not been sufficiently studied until recently, especially on peat soils, as well as the selection of varieties and hybrids according to maturity groups, the establishment of optimal sowing dates, the effectiveness of fertilization and the use of plant growth regulators, etc.

The aim of the research. The purpose of the research is to carry out an agroclimatic substantiation of the possibility and feasibility of growing corn for grain on the drained lands of the Western Polissia zone.

Research materials and methods. In 2019, the Sarnenska Research Station of the National Academy of Agrarian Sciences of Ukraine began studying the possibility of growing corn for grain on drained sod-podzolic and peat soils.

Research methodology. Research on the selection of the most productive and adapted corn hybrids for grain is carried out on the drained peat-boggy massif of the "Chemerne" Sarnenska experimental station (Rivne region).

In terms of morphological characteristics, botanical composition, water-physical and agrochemical properties, this massif is typical for the Western Polissia – a deep, medium-ash non-flooding hypnotic-sedge swamp of the lowland type.

In addition to peat soils, the land use of the station includes turf-podzolic soils. These soil types are the most common in the Western Polissia zone, so the data obtained here are representative for the entire region.

The soils of the experimental sites (peat and sod-podzolic soils) have a slightly acidic reaction of the soil environment (pH_{salt} 4.6–5.0).

Research results. When planning the cultivation of corn in the Western Polissia zone, it should be remembered that there are many limiting factors and nuances of the technology, without taking into account which it is impossible to fully reveal its potential. These main limiting factors include the low natural fertility of most soils in this zone, high acidity, and high variegation of the soil cover, and corn is one of the most demanding crops in terms of the level of fertility and fertilization of crops. In addition, one of the main conditions for obtaining a high grain yield of this crop is a sufficient amount of moisture in the soil [3, 10, 12].

Thermal resources are also more limited in the Polissia zone compared to the Forest-Steppe and Steppe zones (shorter growing season, lower sum of active temperatures, etc.). In addition, it is necessary to approach the timing of sowing and the choice of maturity group of hybrids very carefully, because in Polissia there is always a threat of late spring frosts, which can be observed even at the end of May, and the first autumn frosts can come already at the beginning of September, causing significant damage to crops. However, the western and northern regions of Ukraine are a territory where there is still enough moisture, without which it is problematic to achieve a good corn harvest [11–14].

The main indicators that characterize the heat supply of plants during the growing season are the average monthly air temperatures and their anomalies, the dates of the beginning and end of different temperature periods, in particular, the growing season (warm) and the period of active vegetation, the sum of active and effective temperatures, and others [15].

The dates of stable transition of the average daily air temperature through 0, 5, 10, and 15 °C and the duration of periods with temperatures above these limits are used to determine the duration of vegetation of cold-resistant (period with a temperature above 5 °C) and heat-loving (above 10 °C) crops, during the period of their intensive growth (over 15 °C), when planning the dates of the start of fieldwork in the spring (dates of transition through 5 °C) and their termination (transition through 0 °C) in autumn, etc. (Table 1).

Analysis of the dates of stable temperature transition confirms the tendency of recent decades towards an earlier start of the growing season (on average 10 days earlier than normal) and a later end, which ultimately results in an increase in the duration of the growing season by an average of 11 days. Over the years of research, its duration ranged from 186 to 248 days with an average

1. Dates of stable transition of temperature through 0, 5, 10, 15 °C and the duration of the corresponding periods on the drained peat-boggy massif "Chemerne" (Rivne region), average for 2007–2021

Value	The dates of the temperature transition through certain limits and the duration of the corresponding periods											
	> 0°	< 0°	days	> 5°	< 5°	days	> 10°	< 10°	days	> 15°	< 15°	days
$D_{average}$	24.02	5.12	284	25.03	30.10	217	22.04	3.10	163	12.05	7.09	116
D_{min}	26.01	9.11	254	14.03	6.10	186	4.04	24.09	128	27.04	24.08	100
D_{max}	30.03	31.11	331	11.04	25.11	248	30.04	23.10	188	7.06	18.09	141

of 217 days. The duration of the active growing season (with temperatures > 10 °C) exceeded the norm by an average of 5 days, and the intensive growing season (>15 °C) by 10 days. In most cases, the growing season on the station's peat swamp massif began in the III-rd ten days of March, and the active growing season began in the III-rd ten days of April.

It should be noted that according to the data of Belarusian scientists (Republican Center of Hydrometeorology) in the territory of Belarusian Polissia, since 1989, an abnormally early steady transition of the air temperature past 0 °C in spring has also been registered. On average, from 1989–2015, the transition of air temperature through 0 °C in spring occurs 8–13 days earlier than the multi-year dates. The transition of air temperature by 5 and 10 °C in spring also occurs earlier than multi-year dates by 7–10 and 2–7 days, respectively [16, 17]. These data are fully consistent with the data of our weather station in almost all key indicators.

When planning the cultivation of corn for grain in the Western Polissia zone, it should be remembered that this is a heat-loving crop, so the selection of the maturity group of hybrids should be carefully considered, taking into account the limited thermal resources of this soil-climatic zone [3, 9, 10].

Recently, breeders have created many new precocious corn hybrids specifically for growing in conditions of limited thermal resources, which significantly expands the window of opportunity for growing corn for grain [3].

It is known that the sums of active temperatures during the period of active vegetation in the Polissia zone in different years range from 2140 to 2600 °C. The sum of active temperatures at which early-ripening hybrids reach is 2100–2200 °C, mid-early and mid-ripening – 2400–2600 °C, and late-ripening – 2800–3200 °C. There are several options for dividing hybrids by maturity groups. One of them is given in the Table. 2.

However, during the vegetation period, crops of heat-loving crops use less active heat than the amount that enters the areas of the Western Polissia zone. This is because the growing season is limited by spring and autumn frosts, as well as the late sowing of corn. According to the data of scientific institutions, the frequency of reaching different maturity groups of corn hybrids with different heat supplies is characterized by the following data, fig. 1.

Research by scientific institutions has established that in the Polissya zone, stable growth of early hybrids is possible only with the sum of active temperatures above 10°C – 2800°C. These materials indicate that at an active heat of 2400°C, early-ripening varieties of corn reach 60 %, medium-ripening – 50 %, medium-early – 30 %, and medium-late – 10 %. Full maturation of medium-early and

2. The need of different groups of varieties and hybrids of corn in warmth during the growing season

Ripeness group	The sum of the active temperatures, above 10 °C	FAO number	Vegetation period, days**	Number of leaves
Very early ripening	2100	100–149	80–90	10–12
Early ripening	2200	150–199	90–100	12–14
Mid-morning	2400	200–299	100–115	14–16
Medium ripe	2600	300–399	115–120	17–18
Mid-late	2800	400–499	120–130	19–20
Late ripening	2900–3000	500–599	135–140	21–23
Very late ripening	> 3000	>600	>140	>23

* the temperature exceeding 10 °C is summed

** from emergence to maturity.

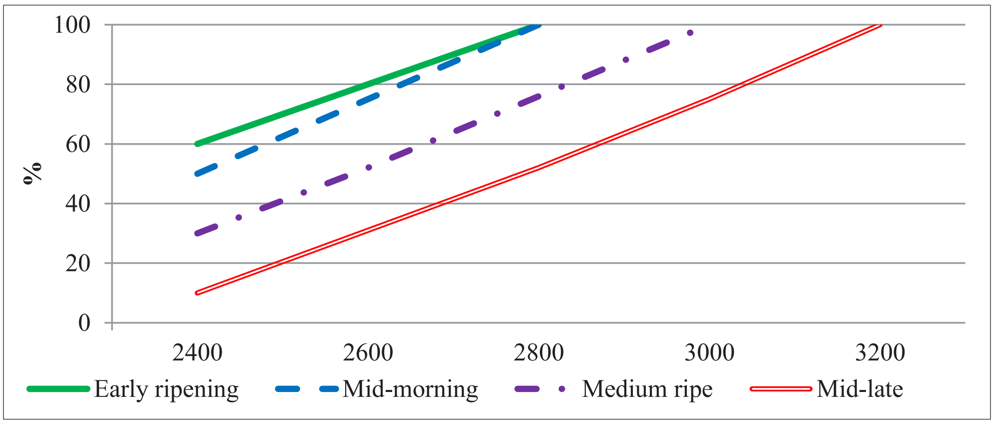

Fig. 1. The probability of reaching corn hybrids of different maturity groups at different sums of active temperatures

early-ripening hybrids occurs at the sum of active temperatures – 2800 °C, medium-late – 3200 °C and medium-ripening – 3000 °C.

Based on the above data, when choosing corn hybrids by maturity groups, one should be guided by the recommendations for the zonal placement of corn crops depending on the FAO index [18], which is shown in Fig. 2.

It should be noted that since 2000, both the duration of the growing season and its heat supply have been increasing most intensively. Since 2010, the sum of active temperatures during the period of active vegetation in most years has consistently exceeded 2600 °C, while 25–30 years ago this indicator reached this mark only in some years (Fig. 3).

The dynamics of the sum of active temperatures (>10 °C) over the last 10 years exceeded 2600 ºC in 8 years. Based on the above data, it can be stated that on the sod-podzolic soils of the Western Polissia zone, it is possible to grow not only early-ripening, but also mid-early hybrids of corn with FAO 250–260. However, in years with minimal amounts of active heat, it is sufficient only to reach the earliest varieties and hybrids of corn.

The hydrothermal conditions of the period of active vegetation (PAV) on the drained peat-boggy massif of the Sarnenska research station for the last 5 years are shown in the table 3.

The coefficient of significance of deviations (anomalies) of the weather indicator of a specific year from long-term average annual

Ki ≤ 1 agro-climatic characteristics of the year are close to usual (long-term average annual)

1 < Ki ≤ 2 agroclimatic characteristics of the year are significantly different from long-term average annual – *italics.*

Ki > 2 agroclimatic characteristics this year are approaching rare (exceptional, extreme) – **bold.**

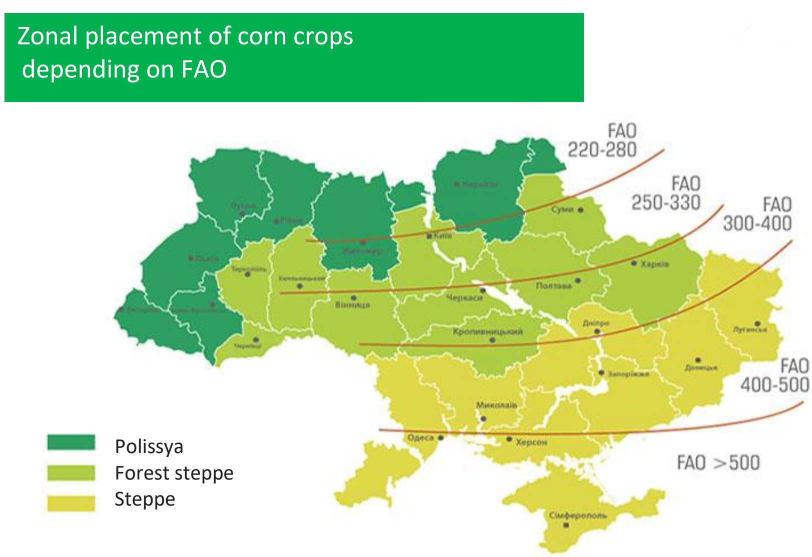

Fig. 2. Recommended zonal placement of corn crops depending on the FAO indicator

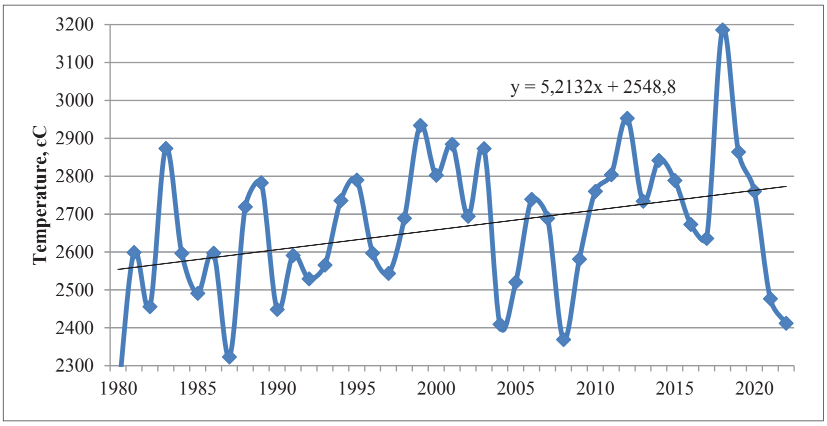

Fig. 3. Dynamics of the sum of active temperatures above 10 °C for the peat-boggy massif "Chemerne" in 1980–2022

3. Hydrothermal conditions of the period of active vegetation (PAV) on the drained peat-boggy massif of the Sarnenska research station

Year	**Period of active vegetation (PAV)**			**The average tempera-ture of PAV, °C**	**The sum of active tempera-tures during PAV, °C**	**Amount of precipitation, mm**	**HTC**
	start (spring)	**finish (autumn)**	**duration**				
2018	**4.04**	*19.10*	**198**	16.9	**3186**	247.8	0,*78*
2019	23.04	**28.10**	*188*	16.2	*2864*	323,1	1,13
2020	28.04	*16.10*	171	16.7	*2760*	341,9	1,24
2021	30.04	*18.09*	*141*	*18.0*	2477	228,2	0,92
2022	24.04	20.09	149	16.8	2412	*200,5*	*0,83*
Average	**22.04**	**08.10**	169	16.9	2740	268,3	0,98
Minimum	04.04	18.09	141	16.2	2412	200,5	0,78
Maximum	30.04	28.10	198	18.0	3186	341,9	1,24
The amplitude, days	26	40	57	1.8	774	141,4	0,46
long-term average annual	26.04	30.09	158	16.3	2498	302,2	1,23
Δ aver. to long-term average annual	−4	+8	+11	+0,6	+243	−33,9	−0,25

The duration of the period of active vegetation in 2018 was 198 days, and this is the second indicator for the entire time of systematic weather observations at the station (78 years, in 1967 it was 214 days). Reliability of indicator P = 2.2 %, repeatability N= once every 46 years.

The sum of active temperatures according to PAW in 2018 was 3186°C, which is the highest indicator during systematic weather observations at the station (reliability of indicator P = 0.9 %, repeatability N = 111 years, i.e. 1 time in 111 years)

In general, it should be noted that the hydrothermal conditions during the period of active vegetation in the peat-boggy massif of the Sarnenska experimental station were characterized by high variability over the years of research.

One of the dangerous meteorological phenomena that complicates the cultivation of corn for grain in the Polissia zone is a short frost-free period. The dates of late spring and early autumn frosts over the past 5 years in the "Chemerne" peat-boggy massif (Rivne region) are given in the Table. 4.

According to the weather station of the Sarnenska research station, which is located directly on the peat-boggy massif, in some years the last spring frosts in the Western Polissia zone

4. The duration of the frost-free period on the drained peat-boggy massif of the Sarnenskф Research Station over the past 5 years

Year	Date of last spring frost in the air	Date of first autumn frost in the air	The duration of the frost-free period
2018	28.04	26.09	150
2019	09.05	19.09	132
2020	21.05	20.09	121
2021	09.05	05.09	118
2022	24.05	01.09	99
2023	14.05	8.09	117
Long-term average annual	**08.05**	**23.09**	137

can be observed even at the end of May, and the first autumn frosts can be observed already in the first days of September, as it was in 2021–2022. The average long-term duration of the frost-free period on the "Chemerne" peat-boggy massif is 137 days. However, there are years with an abnormally short frost-free period. So, for example, in 2022, the frost-free period was only 99 days.

A valuable biological feature of corn is that until the 5–6 leaf phase, its growth point is in the soil, which allows the crops to withstand late spring frosts, which in the Polissia zone can be observed throughout May. According to long-term observations of station scientists, late spring frosts in very rare cases can destroy corn crops. Usually, only the above-ground part of the plant is damaged, while the growing point of corn remains undamaged in 90 % of cases. A valuable biological feature of corn is that up to the 6–7th leaf, the growth point of corn is still in the soil, therefore, even if the above-ground part is severely damaged by frost, its root system continues to develop during this period and the regrowth of the crop occurs with an already well-developed root system [3, 4].

In the experiments of the station, which were carried out on drained peatlands, cases were repeatedly noted when corn seedlings completely died due to the harmful effects of frost, but the growth point in the soil remained intact, and after 8–10 days, regrowth of corn plants took place. In addition, reseeded plots of corn did not provide higher grain yields than those that were affected by frost and re-grown again without reseeding.

The station's research shows that early autumn frosts are extremely dangerous for corn, as adult corn plants die already at a temperature of –1°C. In some years, the first autumn frosts in the Polissia zone can be observed in the first decade of September (especially on peat soils and low relief elements). Therefore, only the most early-ripening hybrids of corn with FAO up to 200–220 will have time to form a full-grain crop. By choosing late-ripening hybrids, there is a risk of a significant shortfall in the harvest or even its complete loss due to the premature termination of vegetation caused by frost.

Changes in the temperature regime of the soil. Climate changes observed in the last decade create new conditions for growing crops. Knowledge of changes in the parameters of the hydrothermal regime of the soil in the context of climatic changes and, accordingly, clarification of the terms of sowing of the main crops are especially relevant. The key indicator for determining when to sow corn is the temperature of the 0–10 cm soil layer. The optimal indicator for its sowing is the soil temperature in the 0–10 cm layer – 10 °C. According to the archive data of the station, 50–60 years ago, such soil temperature on the peat soils of the station occurred at the beginning of the second 10 ten days of May [19]. Based on the data of the temperature regime of the soil of the last 5 years (data of the meteorological station of the station), the temperature of the soil in the layer of 0–10 cm on peat soils reaches 10 °C at the end of the third ten-day period of April, which is optimal for sowing corn for grain [20]. This indicates the expediency of shifting the terms of sowing corn for grain in the Western Polissia zone to earlier – by 8–12 days.

The research conducted in recent years at the Agrarian Polygon of "Zakhidagroprom" LLC shows that due to modern climate changes, namely the significant warming of the climate, it is possible to grow corn for grain in the Western Polissia zone. In some years, even medium-ripe corn hybrids with FAO 310–330 had time to form physiologically ripe grain [6].

In addition, in recent decades, breeders have created many early-ripening and cold-resistant corn hybrids, suitable for growing in conditions of limited thermal resources.

So, summarizing the above, corn should be sown in the Western Polissia zone as early as possible, as soon as the temperature in the 0–10 cm soil layer reaches 8–10 °C, which mostly falls at the end of the third ten-day period of April. If cold-resistant hybrids are used, sowing can be started from April 22–23, when the temperature in the 0–10 cm soil layer reaches 8 °C. In the spring, mineral soils warm up faster than peat soils, so corn sowing can be started here a few days earlier.

Early periods of corn sowing contribute to the effective use of winter moisture reserves, and the flowering of plants does not fall on a critical temperature period. Late sowing times slow down the ripening period by 17–20 days, while the moisture content of the grain is quite often 30 % or more, and its drying to basic indicators requires almost half of the energy resources from the total amount of them for cultivation [3, 4, 10, 11, 21].

The research of the station shows that the relative humidity of the air on peat soils is 10–12 % higher than on the adjacent terrestrial soils, which is associated with a significant saturation of the ground air layer with water vapor due to the evaporation of the peat soil. Therefore, when growing on peat soils, corn hybrids with the highest moisture yield should be chosen.

The yield of corn on drained sod-podzolic and peat soils of the Sarnenska Research Station of the IWPaLR of NAAS of Ukraine in the cross-section of hybrids of different maturity groups is shown in the table. 5–6.

As the conducted studies showed, during 2019–2021, the highest grain yield indicators had the Dekalb company's hybrids – DK 315 and DKS 3969 – 10.30 and 9.43 t/ha, respectively. A high yield rate was also noted for the Pandoras hybrid of Syngenta selection – 9.27 t/ha. Hybrids of domestic selection – Yarovets 234 MV and Orlyk were inferior to hybrids of foreign selection in terms of grain yield. Their average yield over 3 years was 7.68 and 7.50 t/ha.

Drained peat soils have a high nitrogen content and sufficient moisture, making them well-suited for growing corn. However, there are several limiting factors and nuances of technology, which have to be taken into account to achieve a high yield of corn grain on peat soils. The main limiting factor in achieving a high corn grain yield on peat soils is less favorable microclimatic conditions (less amount of active heat, shorter growing season and frost-free period, etc.) than on nearby land soils. Therefore, the yield of corn on peat soils varies significantly over the years of research and largely depends on the agrometeorological conditions of a particular year. The most significant influence is exerted by the duration of the frost-free period of a particular year and especially the timing of the onset of the first autumn frosts, most of which cause premature termination of the growing season and a shortage of crops due to insufficient grain filling. Comparing the data in tables 4 and 5, it can be seen that with a reduction in the duration of the frost-free period, there is a significant decrease in the yield of corn grain.

When growing corn for grain in the Western Polissia zone, one of the important elements of growing technology is the sowing time. Their effect on corn yield is reflected by the research results obtained in field experiments in 2022 (Table 6).

The data in Table 6 confirm the critical importance of observing the optimal corn sowing dates in the Western Polissia zone. A 16-day delay in sowing led to a decrease in corn yield to 30–35 %. Corn hybrids sown later did not have time to form a well-filled grain before the onset of the first autumn frosts, which in 2022 occurred abnormally early – in the first ten days of September.

5. The yield of corn hybrids of different maturity groups when grown on drained peat soils, (application of $N_{35}P_{60}K_{90}$)

Hybrids	**FAO number**	**Productivity at 14 % basic humidity, t/ha**			**Average**
		2019	**2020**	**2021**	
ДК 315 (Dekalb)	310	10.67	11.06	9.17	10,30
ДКS 3969 (Dekalb)	310	9.79	10.29	8.20	9,43
Pandoras (Syngenta)	250	10.01	10.22	7.57	9,27
Kan'yons (KWS)	230	7.95	8.96	6.79	7,90
Yarovets 234 MV (NAAS)	240	8.01	8.54	6.48	7,68
Orlyk (NAAS)	280	8.12	7.98	6.39	7,50
$LSD_{0,5}$ t/ha		0,441	0.389	0.402	

6. The yield of corn hybrids on sod-podzolic light loamy soils of the Sarnenska Research Station, 2022

Sowing date	Hybrid	Originator	FAO number	Productivity, t/ha	
				sod-podzolic soils	peat soils
9. 05.2022	P 8521	Pioneer USA	220	9.33	8.22
	P 7948	Pioneer USA	210	10.30	8.39
	ДКS 3730	Dekalb USA	280	12.48	8.44
	P 9234	Pioneer USA	320	12.81	6.73
	P8834	Pioneer США	280	13.45	7.47
	P 8812	Pioneer USA	290	13.64	7.01
	ДК 315	Dekalb USA	310	14.88	9.24
The average of 7 hybrids				**12.41**	**7.93**
27. 05.2022	P 7043	Pioneer USA	160	7.61	6.26
	ДКS 3441	Dekalb USA	220	8.37	5.86
	Marimba	Syngenta Switzerland	240	8.25	4.44
	Fortago	Syngenta Switzerland	260	8.04	5.21
	Foton	Syngenta Switzerland	260	9.55	4.55
The average of 5 hybrids				8.36	5.26

Fertilization system ($N_{90}P_{90}K_{90}$ + phosphorus-mobilizing agent Rice Pi turf-podzolic soils; and $N_{60}P_{60}K_{120}$ + phosphorus-mobilizing agent Rice Pi – peat soils)

In the technology of growing corn, the fertilization system is important, because it is one of the most demanding crops in terms of soil fertility and the level of mineral nutrition [1, 3, 12].

The results of studies on determining the effect of fertilization systems on the yield of corn on sod-podzolic and peat soils are shown in the Table 7.

The analysis of corn yield shows that depending on the fertilization system, the grain yield on peat soils was in the range of 3.66–9.34 t/ha and 10.91–13.93 t/ha on sod-podzolic light loamy soils. The significantly lower yield of corn per

7. The influence of fertilization systems on the yield of corn hybrid DK 315 (Dekalb) on the drained lands of the Sarnenska experimental station of the IWPaLR of NAAS of Ukraine, 2021–2023

Fertilizations options and biopreparations	Productivity, t/ha	± to control		± to standart	
		t/ha	%	t/ha	%
Sod-podzolic light loamy soils					
$N_{30}P_{30}K_{30}$ (control)	10.91	–	–	–	–
PPP (Biosil + Stimpo + Regoplant)	12.19	1.28	1.17	–	–
Phosphorus-mobilizing agent Rice Pi	12.67	1.76	1.61	–	–
$N_{90}P_{90}K_{90}$ (standart)	13.03	2.12	1.94	–	–
$N_{90}P_{90}K_{90}$ + PPP (Biosil + Stimpo + Regoplant)	13.56	2.65	2.43	0.53	0.41
$N_{90}P_{90}K_{90}$ + Phosphorus-mobilizing agent Rice Pi	13.93	3.02	2.77	0.90	0.69
$LSD_{0.5,\ t}$/ha	0.409				
Peat soils					
Without fertilization (control)	3.66	–	–	–	–
PPP (Biosil + Stimpo + Regoplant)	4.83	1.17	3.20	–	–
Phosphorus-mobilizing agent Rice Pi	5.25	1.59	4.34	–	–
$N_{35}P_{60}K_{120}$ (standart)	8.08	4.42	12.08	–	–
$N_{35}P_{60}K_{120}$ + PPP (Biosil + Stimpo + Regoplant)	8.75	5.09	13.91	0.67	0.83
$N_{35}P_{60}K_{120}$ + Phosphorus-mobilizing agent Rice Pi	9.34	5.68	15.52	1.26	1.56
LSD $_{0.5,\ t}$/ha	0.334				

grain on peat soils is explained by the fact that the corn vegetation here for 2 years in a row (2021–2022) was stopped in the first ten days of September due to abnormally early autumn frosts, which did not allow the full potential of the studied hybrids to be realized.

During this period, no frost was observed on turf-podzolic soils located nearby on dry land, which allowed the full potential of the studied corn hybrids to be realized.

Regarding the effectiveness of the researched fertilization systems, the use of plant growth regulators Biosil, Stimpo, and Regoplant ensured an increase in the yield of corn per grain on sod-podzolic soils by 1.28 t/ha or by 11.7 % and on peat soils by 1.17 t/ha ha or 32.0 %. The use of the phosphorus-mobilizing drug Rice Pi increased the yield of corn on sod-podzolic soils by 1.76 t/ha or 16.1 % and on peat soils by 1.59 t/ha or 43.4 %.

Application of the mineral fertilization system on sod-podzolic soils ensured an increase in yield by 2.12 t/ha or 19.4 % and on peat soils by 4.42 t/ha or 120.8 %.

The use of a mineral fertilizer system in combination with plant growth regulators Biosil and Stimpo ensured an increase in the yield of corn on sod-podzolic soils by 2.65 t/ha or by 24.3 % and on peat soils by 5.09 t/ha or 139.1 %. The combination of the mineral fertilizer system with the phosphorus-mobilizing agent Rice Pi ensured an increase in the yield of corn on sod-podzolic soils by 3.02 t/ha or by 27.7 % and on peat soils by 5.68 t/ha or 155.2 %.

Apart from small-scale experiments, in 2019–2021 the Sarnen research station carried out research on the adaptation and introduction of new varieties and hybrids of crops and their cultivation technologies in modern soil and climatic conditions for the maximum realization of the agricultural resource potential of the reclaimed agro-landscapes of Western Polissia.

During 2019–2021, researches were carried out with corn on 3 types of drained soils (organogenic, mineral, and organomineral). Organogenic soils are represented by thick peat soils, mineral soils are soddy-podzolic sandy loam soils, and organic-mineral soils are soddy-podzolic peat soils.

The total area of experimental plots in 2019–2021 on soddy-podzolic sandy loam soils was 89.0 hectares, peat soils – 292.0 hectares, and organomineral soils – 19.5 hectares. For the research, a mid-season corn hybrid DK 315 of the Dekalb brand from FAO 310 was chosen.

The fertilization system for mineral and organomineral soils consisted of applying complete mineral fertilizer at the rate of $N_{100}P_{60}K_{60}$. Mineral fertilizers were applied in the form of nitroammophoska NPK 16:16:16 and carbamide.

On peat soils, the fertilization system consisted in the application of complete mineral fertilizer at the rate of $N_{18}P_{60}K_{90}$ + application of 2 t/ha of dolomite flour. Mineral fertilizers were applied in the form of polyphoska 6–300 kg in physical weight. Additionally, 2 c/ha of dolomite flour was applied.

In addition, to reduce the acidity of peat soils, liming was carried out at the rate of 2 t/ha of $CaCO_3$.

In general, during 2019–2021, the yield of corn per grain was as follows (Fig. 4):

2019 on turf-podzolic soils 7.75 t/ha, on peat – 8.81 t/ha, on organic-mineral – 10.36 t/ha.

2020 on sod-podzolic soils – 11.51 t/ha, on peat – 11.05 t/ha, on organo-mineral – 13.67 t/ha.

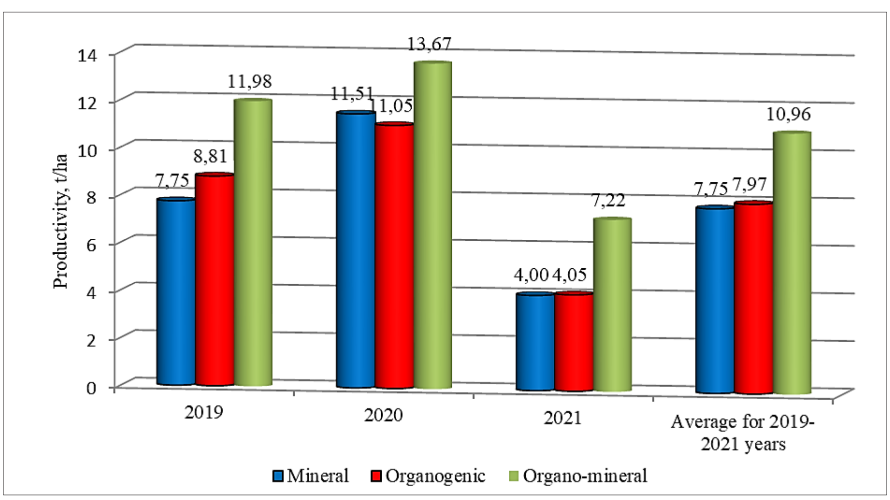

Fig. 4. Maize yield of the DK 315 hybrid on different types of drained soils of the Sarny Research Station

2021 on sod-podzolic soils – 4.00 t/ha, on peat – 4.04 t/ha, on organo-mineral – 7.22 t/ha.

In the conditions of 2021, the lowest yield of corn grain was obtained in 3 years. Such a decline in productivity is explained by a complex of negative factors that developed in the conditions of 2021, namely:

– in July, there was a long-term air drought, which led to poor pollination of corn heads, which resulted in a significant shortfall in harvest compared to previous years;

– premature cessation of vegetation caused by abnormally early autumn frosts noted in the first ten days of September;

– abnormally cold April, due to which corn sowing in 2021 was carried out 12–14 days later compared to the previous 2019–2020 years.

The above complex of factors caused a sharp decrease in the yield of corn in 2021 compared to the previous 2 years.

On average, over the 3-year cycle of research, the yield of corn per grain on sod-podzolic soils was 7.75 t/ha, on peat soils – 7.97 t/ha, on organo-mineral soils – 10.96 t/ha. It should be noted that the highest rates of corn yield per grain were obtained when grown specifically on organo-mineral soils (peatted sod-podzolic soils bordering lowland peat soils).

In general, the results of field studies 2019–2021 indicate a significant impact of weather conditions during the active growing season of a particular year on corn yield. Analyzing the data in Table 3, it was established that the most favorable hydrothermal conditions for growing corn for grain were in 2019–2020, when the HTC was 1.13 and 1.24, respectively, and the duration of the period of active vegetation was 188 and 171 days, respectively. The amount of precipitation in these years was 323 and 342 mm, which is close to the long-term norm. The analysis of the yield of corn per grain shows that it was in 2019–2020 that the highest yield indicators were obtained in the experiments, regardless of the type of soil.

Also, studies have shown that when planning to grow corn in the Western Polissia zone, especially on peat soils, it is necessary to observe the earliest possible sowing dates, as well as to choose early-ripening corn hybrids with FAO up to 220–240, so that before the first autumn frosts, the plants have time to form a well-filled and physiologically ripe grain.

Conclusions. The analysis of the main hydrothermal indicators shows that with the current indicators of the heat supply of the growing season in the zone of the Western Polissia on sod-podzolic soils, it is possible to achieve not only early-ripening but even mid-early hybrids of corn with FAO up to 280–300. At the same time, when growing on peat soils in years with minimal amounts of active heat, it is enough only to reach the most early-ripening hybrids of corn with FAO up to 220–240. By choosing late-ripening hybrids, there is a risk of a significant crop shortage.

The results of the station's experimental research showed that under favorable conditions on the most fertile slopes of drained sod-podzolic soils of the Western Polissia zone, with intensive technologies, it is possible to obtain more than 12.0 t/ha of corn grain.

Drained peat soils, due to their high nitrogen content and sufficient amount of moisture, have sufficient potential for obtaining a high yield of corn grain. However, its indicators by research years vary greatly and largely depend on the agrometeorological conditions of the growing season of a particular year.

It was established that the main limiting factors for achieving a high yield of corn grain on peat soils are less favorable microclimatic features (less active heat, shorter growing season and frost-free period, etc.). It was found that the highest yield of corn per grain both on sod-podzolic and peat soils was provided by the organo-mineral fertilization system, which was based on the application of complete mineral fertilizer in the norm of $N_{90}P_{90}K_{90}$ on turf-podzolic soils and $N_{35}P_{60}K_{120}$ on peat soils in combination with phosphorus-mobilizing agent Rice Pi.

The application of an organomineral fertilization system ($N_{90}P_{90}K_{90}$ + phosphorus-mobilizing drug Rice Pi) increased the yield of corn on sod-podzolic soils by 3.02 t/ha compared to the basic fertilizer system ($N_{30}P_{30}K_{30}$). The use of an organo-mineral fertilization system ($N_{35}P_{60}K_{120}$+ phosphorus-mobilizing agent Rice Pi) ensured an increase in the yield of corn on peat soils by 5.68 t/ha compared to the natural background of fertility.

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УДК 633.34:631.4

ОСОБЛИВОСТІ ВИРОЩУВАННЯ КУКУРУДЗИ НА ЗЕРНО НА ОСУШУВАНИХ ЗЕМЛЯХ У ЗОНІ ЗАХІДНОГО ПОЛІССЯ УКРАЇНИ В УМОВАХ СУЧАСНИХ КЛІМАТИЧНИХ ЗМІН

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Анотація. *Сучасні кліматичні зміни, а саме суттєве потепління, в зонах північного Лісостепу та Полісся України сприяє вирощуванню низки зернових та зернобобових культур (кукурудза на зерно, соя, соняшник та ін), раніше непритаманних для цього регіону. Серед вищевказаних культур кукурудза володіє найбільшим потенціалом урожайності зерна, тому є однією з найбільш поширених культур у світовому землеробстві. Якщо ще 10–15 років тому вирощування кукурудзи на зерно в зоні Полісся не практикували, то останнім часом її посівні площі істотно виросли, а врожайність не поступається традиційним для цієї культури регіонам Лісостепу та Степу. Результати експериментальних досліджень Сарненської дослідної станції показали, що в сприятливих умовах на найродючіших відмінах осушуваних дерново-підзолистих ґрунтів зони Західного Полісся при інтенсивних технологіях можна одержати понад 10–12 т/га зерна кукурудзи. Аналіз гідротермічних показників свідчить, що при нинішніх показниках теплозабезпеченості вегетаційного періоду в зоні Західного Полісся на мінеральних ґрунтах можливе достигання не тільки ранньостиглих, а навіть середньоранніх гібридів кукурудзи з ФАО до 280–300. Осушувані торфові ґрунти завдяки високому вмісту азоту та достатній кількості вологи володіють потрібним потенціалом для одержання високої урожайності зерна кукурудзи. Однак її показники по роках досліджень сильно варіюють і значною мірою залежать від агрометеорологічних умов вегетаційного періоду конкретного року. Встановлено, що основними обмежуючими чинниками для досягнення високого урожаю зерна кукурудзи на торфових ґрунтах є менш сприятливі мікрокліматичні особливості (менша кількість активного тепла, коротший вегетаційний та без морозний період тощо) порівняно з прилеглими дерново-підзолистими ґрунтами розташованими поряд на суходолі.*

Експериментально встановлено, що в умовах мінімальної тривалості безморозного періоду сформувати повноцінний урожай зерна на осушуваних торфових ґрунтах у зоні Західного Полісся встигнуть лише найбільш ранньостиглі гібриди кукурудзи з ФАО до 220–240. Обравши більш пізньостиглі гібриди існує ризик суттєвого недобору урожаю через передчасне припинення вегетації, спричинене ранніми осінніми заморозками.

Встановлено, що найвищу урожайність кукурудзи на зерно, як на дерново-підзолистих, *так і торфових ґрунтах, забезпечувала органо-мінеральна система удобрення, яка базувалась на внесенні повного мінерального удобрення в нормі $N_{90}P_{90}K_{90}$ на дерново-підзолистих ґрунтах та $N_{35}P_{60}K_{120}$ на торфових ґрунтах у поєднанні з фосформобілізуючим препаратом Райс Пі. Застосування органо-мінеральної системи удобрення ($N_{90}P_{90}K_{90}$ + фосформобілізуючий препарат Райс Пі) забезпечило підвищення урожайності кукурудзи на дерново-підзолистих ґрунтах на 3,02 т/га порівняно з базовою системою удобрення ($N_{30}P_{30}K_{30}$). Застосування органо-мінеральної системи удобрення ($N_{35}P_{60}K_{120}$ + фосформобілізуючий препарат Райс Пі) забезпечило підвищення урожайності кукурудзи на торфових ґрунтах на 5,68 т/га порівняно з природним фоном родючості.*

Ключові слова: *осушувані землі, кукурудза, сорти і гібриди, зона Західного Полісся, зміни клімату, система удобрення*