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EFFICIENCY OF SOWING DATES FOR MAIZE HYBRIDS OF DIFFERENT MATURITY GROUPS IN THE CONDITIONS OF THE WESTERN FOREST STEPPE OF UKRAINE

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Topicality. *In recent decades, maize and sunflower have become strategic crops in the agrarian business of Ukraine, contributing to the country's foreign exchange earnings and providing the lion's share of profits to agricultural producers. Modern maize hybrids have a significant genetic potential to produce high yields, but they need to create appropriate conditions for plant growth and development. To achieve this goal, measures should be applied to optimize the conditions for growing maize at all stages of organogenesis. In the context of climate change towards warming, such technological element as sowing date is becoming increasingly important. A direct correlation between the degree of plant development and sowing date has been established.* ***Purpose.*** *To investigate and identify the most effective elements of maize cultivation technology in the conditions of the Western Forest-Steppe of Ukraine.* ***Materials and Methods.*** *The research was conducted in the fields of breeding crop rotation of the Ternopil State Agricultural Experimental Station of the Institute of Agriculture in the Carpathian Region of NAAS of Ukraine after winter wheat (on the background of $N_{60}P_{30}K_{30}$) according to generally accepted technology.* ***Results.*** *The basis of the development is the study of optimal sowing dates of maize hybrids for grain of different maturity groups. For this purpose, sowing of the first date was carried out at a soil temperature of 8–10 °C at the depth of seed placement, the second date – at 10–12 °C, and the third date – at 12–14 °C. Research results show that for the conditions of the Western Forest-Steppe, the most economically justified is the cultivation of the early-ripening hybrid DN Khortytsia, when the soil temperature reaches up to 10–12 °C. Considering the conditions of growing four maize hybrids for grain of different maturity groups, as well as different sowing dates, the highest grain yield (10.1 t/ha) and economic efficiency (147.7 % profitability) were obtained when growing the hybrid DN Khortytsia.* ***Conclusions.*** *The research results showed that sowing maize hybrids for grain of different maturity groups at the optimum date solves such problems as the rational nutrient and soil moisture utilisation, weed and pest control, improvement of physical and chemical properties of the soil, increased efficiency of fertiliser and machinery application, and cheapening of agricultural products.*

Key words: *maize hybrids for grain, elements of cultivation technology, soil temperature, crop structure, productivity, economic efficiency.*

Introduction. Maize (*Zea mays* L.) is one of the most highly productive crops for universal use, which exceeds many crops in terms of yield under conditions of sufficient moisture availability. At the same time, maize is characterised by a high drought tolerance. The crop is widely used in the food, livestock and pharmaceutical industries. Grain maize production is the fastest growing segment in the overall structure of Ukrainian agricultural production. Over the recent decade, the area under maize cultivation has more than doubled, and maize yield has increased significantly. This development was primarily driven by the global food crisis, which contributed to the increased demand for the crop. Today, maize grain accounts for the bulk of the total grain proposition and is the top export commodity in Ukraine [1].

The main reserve for increasing gross harvest of maize has been and remains an enhancement of its yields based on more efficient utilisation of the genetic potential of new hybrids, which enables a 20–30 % increase in productivity. The right choice of maize hyb-

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rids in accordance with soil and climatic conditions is a key factor for high yields. The realisation of the biological potential in the crops can be enhanced through the introduction of modern, efficient and competitive agricultural technologies, which should be based on the selection of highly productive hybrids that are adapted to the zone and optimised sowing dates in specific soil and climatic conditions [2, 7].

Grain crop production has traditionally been at the forefront of the crop production structure and the overall agricultural production in Ukraine. Agricultural producers receive almost a third of their cash receipts from selling grain crops. The overall demand for grain in the country is determined by the amount of grain produced for food, processing, feed, seeds, exports and state reserves. In this scope, grain consumed by livestock and used as a foodstuff for the population accounts for the largest share [3].

Maize has always held a leading position in the grain and feed balance. Domestic scientific experience shows that this crop is virtually unrivalled in terms of its potential for grain and green mass production, feed and energy value and is indispensable in livestock rations, especially for pigs and poultry. Enhancing the gross harvest of maize has been and remains a priority for agricultural production [4, 5].

Strong demand for maize remains on the global market. Despite an increase in the domestic market supply, maize grain remains the most profitable for domestic farmers. Therefore, it is not surprising that in terms of production volumes, maize is one of the top crops in the grain group [6].

The optimal sowing date for maize hybrids of different maturity groups is the steady warming of the soil to 10–12 °C at the depth of seed placement. Both too early and late sowing dates reduce the grain yield of the crop. However, with early sowing dates (steady soil warming up to 8–10 °C), the flowering of tassels in maize plants occurs earlier than with late sowing dates, which allows early crops to consume soil moisture reserves more efficiently and to reduce the risk of negative impact of drought on crop plants during the most important stages of the growing season [9].

In early ripening and mid-early hybrids, as a rule, the yield changes insignificantly at late sowing dates. Genetic potential of late-ripening hybrids is better realised in the case of early sowing when the soil temperature reaches 8–10 °C. At the same time, all biotypes have the lowest grain moisture content at harvest when sown in early dates. For early sowing, we should consider the cold resistance level of the hybrid and apply appropriate technological protection methods during seed preparation (obligatory seed incrustation with a complex of fungicidal disinfectant, microelements, growth regulator) [7].

While deciding on the sowing dates of maize, it is necessary to consider the probability of frosts in the early development stages of plants, which can cause significant damage to the aboveground plant parts.

Materials and Methods. The research was carried out on the fields of breeding crop rotation of the Ternopil State Agricultural Research Station of the Institute of Agriculture in the Carpathian region of NAAS. The soil of the plots is a deep low-humus chernozem of medium loamy granulometric composition with the following agrochemical parameters of the arable layer (0–30 cm): humus content – 3.52 %; salt pH – 5.7; hydrolytic acidity – 2.21 mg eq./100 g of dry soil; low soil availability of alkaline hydrolysed nitrogen - 126.0 mg/kg of soil (according to Kornfield), increased availability of phosphorus – 123.0 mg/100 g of air-dry soil (according to Chirikov) and increased availability of potassium – 92.0 mg/100 g of air-dry soil (according to Chirikov).

The zone has a moderately continental climate with sufficient moisture. In the course of field trials, we used the available scientific experience in maize cultivation in the Western Forest-Steppe zone and generally accepted methodological recommendations.

The research was carried out during 2019–2020, with the early-ripening hybrid DN Nur (FAO 150), mid-early hybrids DN Khortytsia (FAO 240) and DN Slavytsia (FAO 270), and mid-ripening hybrid DN Drah (FAO 340). Sowing was carried out in three dates: the first date was 15 April, at a soil temperature of 8–10 °C at the depth of seed placement, the second – 24 April (at a soil temperature of 10–12 °C), the third – 9 May (at a soil temperature of 12–14 °C). Sowing was carried out with a SPCh-6 seeder with a row spacing of 70 cm. Chemical methods of weed control were used during crop cultivation that included the application of a broad-spectrum soil-applied herbicide Astrel (3.0 l/ha) for controlling annual and perennial dicotyledonous and grass weeds.

Soil preparation in the experiments was generally accepted for the conditions of the zone. We sowed seeds with germination energy of at least 92–95 %. The sowing area of the plot was 100.8 m^2 (4.2 m x 24 m), and the registration area was 50.4 m2 (4.2 m x 12 m). The order of plots and replications is single-tier, sequential.

Observations were made according to the "Methodological recommendations for conducting field experiments on maize" (Dnipropetrovsk, 2008) to study the peculiarities of growth, development and formation of plant productivity in experiments [11].

Soil moisture content was determined before sowing. For this purpose, soil samples were taken diagonally at a depth of 0–100 cm in the horizons of 0–10 cm, 10–20, 20–30, 30–40, 40–60, 60–80, 80–100 cm on the designated experimental plot. Laboratory analyses of soil and plant samples were carried out according to the contract in a certified laboratory of the Ternopil branch of the State Institution "Institute of Soil Protection of Ukraine".

The yield attributes (ear length, ear diameter, ear weight, grain weight per ear, number of kernels per ear, and 1000 grain weight) were determined by analysing the samples of the ears selected during harvesting. Grain moisture content was recorded before harvesting.

Grain yield was calculated according to the "Methodological recommendations for conducting field experiments on maize" (Dnipropetrovsk, 2008) [11].

Results and Discussion. The stability of high maize yield is achieved by improving the adaptability of hybrids to abiotic and biotic factors, namely temperature and moisture conditions, diseases and pests. The growing season conditions in 2019 were mostly favourable for maize. Despite the fact that in spring there was sufficient and sometimes even excessive moisture; in summer there was a deficit of moisture availability. The end of June and beginning of August were quite hot and with low rainfall. Later, at the beginning of tasseling – pollination, the situation with precipitation levelled out, the temperature dropped slightly, which allowed a good pollination of the ears to take place in the vast majority of areas. During the grain filling period, rainfall was local, but there was no critical moisture deficit.

Spring 2020 was characterised by cold weather with frequent frosts. In April, dry weather prevailed with significant variability in air temperature both during the day and the average daily temperature on different days. On average for the month, this indicator was 9.2 °C, compared to the long-term average of 8.3 °C. Despite the slightly elevated background, 9 days with frost were recorded, and on 1 April the minimum air temperature dropped to -6.1 °C.

The average temperature in May was below the long-term average, and precipitation was above the five-year average. Naturally, such agro-climatic conditions were not favourable for the rapid development of maize. Therefore, all stages of ontogenesis were slightly delayed. For example, the flowering stage began 5–7 days later, depending on the sowing date. The abundance of moisture and low temperatures in late spring caused a reduction in the grain rows per ear, which also affected yield. In June, average daily temperatures have risen, but the unstable weather pattern persisted until the end of the month. The average monthly temperature in June was 19.2 °C, compared to the long-term average of 17.3 °C. Total precipitation was significantly higher than the long-term average (82 mm) and amounted to 123 mm. In July, weather indicators were close to the long-term average. In late summer, the weather was dry during the grain filling period.

Thus, over the two years of observations, weather conditions in 2020 compared to 2019 were less favourable for the maize growth and development, and that affected the crop productivity.

At the sowing in 2019, the productive moisture reserves in the one-metre soil layer were 204.8 mm in the first sowing date (the long-term average was 187 mm), in the second – 205.9 mm (182 mm), in the third – 234.6 mm (179 mm), in 2020 – 172.8 mm in the first sowing date, 164.7 mm in the second and 166.9 mm in the third sowing dates (Table 1).

Table 1. Productive moisture reserves at the sowing period depending on the sowing date, mm, (2019–2020)

Sowing date	Soil layer, cm					
	0–20			0–100		
	2019	2020	average	2019	2020	average
I – 15 April	18.1	20.8	19.5	204.8	172.8	188.8
II – 24 April	18.2	18.5	18.3	205.9	164.7	185.3
III – 9 May	19.2	26.4	22.8	234.6	166.9	200.8

On average, the productive moisture reserves in the seed layer (0–20 cm) were 18.1 mm (compared to the long-term average of 38.0 mm) for the first sowing date, 18.2 mm (34.0 mm) and 19.2 mm (32.0 mm) for the second and third sowing dates in 2019; in 2020 – 20.84 mm, 18.5 mm, and 26.4 mm, respectively.

At the harvesting period, in 2019, the productive moisture reserves in the one-metre soil layer were 125.3 mm at the first sowing date, 108.3 mm at the second, and 105.8 mm at the third; in 2020, at the first sowing date – 139.7 mm, at the second – 140.4 mm, and at the third – 136.8 mm (Table 2).

Table 2. Productive moisture reserves at the harvesting period depending on the sowing date, mm, (2019–2020)

Sowing date	Soil layer, cm					
	0–10			0–100		
	2019	2020	average	2019	2020	average
I – 15 April	2.2	12.4	7.3	125.3	139.7	132.5
II – 24 April	1.9	13.1	7.5	108.3	140.4	124.4
III – 9 May	1.8	12.2	7.0	105.8	136.8	121.3

It was found that hybrids of different maturity groups manifested individual characteristics in the formation of yield attributes. Thus, on a two-year average, at the first and second sowing dates, maize hybrids DN Nur, DN Khortytsia, DN Slavytsia and DN Drah showed an increase in the morphological characteristics of ears and yield attributes compared to the third sowing date (Table 3).

The effect of yield attributes on the yield of maize hybrids has been established over the years of research. It was found that the highest yield of maize was obtained when sowing hybrids in the first and second sowing dates. The yield indicators were as follows: in the early-ripening hybrid DN Nur – 8.4–8.7 t/ha, in the mid-early hybrids –DN Khortytsia – 9.3–9.6 t/ha and DN Slavytsia – 8.9–9.1 t/ha, in the mid-ripening hybrid DN Drah – 7.9–8.2 t/ha (Table 4).

Table 3. Yield attributes of maize hybrids depending on sowing dates, (2019–2020)

Hybrid	Sowing date	Ear length, cm	Ear diameter, cm	Ear weight, g	Grain weight per ear, g	Number of kernels per ear, pcs	1000 grain weight, g
DN Nur (FAO 150)	15 April	18.2	4.1	188.0	157.0	470.0	293.0
	24 April	18.7	4.1	190.0	162.0	491.0	296.0
	9 May	18.0	3.9	180.0	157.0	460.0	293.0
DN Khortytsia (FAO 240)	15 April	19.3	4.5	206.0	180.0	536.0	335.0
	24 April	20.6	4.6	231.0	179.0	562.0	325.0
	9 May	18.7	4.3	185.0	170.0	531.0	333.0
DN Slavytsia (FAO 270	15 April	19.8	4.5	195.0	162.0	538.0	304.0
	24 April	20.2	4.7	209.0	170.0	547.0	308.0
	9 May	18.5	4.5	196.0	155.0	516.0	314.0
DN Drah (FAO 340)	15 April	18.0	4.3	178.0	148.0	480.0	287.0
	24 April	18.2	4.4	184.0	153.0	488.0	288.0
	9 May	17.5	4.3	172.0	145.0	475.0	273.0

Table 4. Yield and grain moisture content of maize hybrids depending on sowing dates

Hybrid	Sowing date	Grain yield, t/ha			Grain moisture content, %		
		2019	2020	average	2019	2020	average
DN Nur (FAO 150)	15 April	8.9	7.9	8.4	17.1	22.9	20.0
	24 April	9.2	8.1	8.7	17.4	23.2	20.3
	9 May	8.7	7.6	8.1	17.6	23.5	20.6
DN Khortytsia (FAO 240)	15 April	9.9	8.8	9.3	18.2	24.1	21.2
	24 April	10.1	9.1	9.6	18.8	24.3	21.6
	9 May	9.7	8.3	9.0	19.1	24.9	22.0
DN Slavytsia (FAO 270	15 April	9.4	8.5	8.9	17.6	23.9	20.8
	24 April	9.6	8.7	9.1	18.0	24.1	21.0
	9 May	9.2	8.2	8.7	18.1	24.8	21.5
DN Drah (FAO 340)	15 April	8.2	7.6	7.9	20.5	26.8	23.7
	24 April	8.5	7.9	8.2	20.8	27.3	24.0
	9 May	8.1	7.4	7.8	21.2	28.2	24.7
P, %		1.36	1.34		x	x	X
LSD_{05}, t/ha		0.36	0.30		x	x	x

In 2020, the highest grain yield was recorded in the DN Khortytsia hybrid – 9.1 t/ha at the first sowing date of 24 April, slightly lower – 8.8 t/ha at the second sowing date of 15 April, and the lowest – 8.3 t/ha at the third sowing date of 9 May.

The lowest moisture content at harvesting was in the early ripening hybrid DN Nur (22.9–23.5 %), and the highest moisture content was in the hybrid DN Drah (26.8–28.2 %). When the sowing dates of maize hybrids change from early to late, the pre-harvest grain moisture content is resulted increases.

The economic efficiency of growing maize hybrids of different maturity groups depending on the sowing date in 2019 and 2020 is presented in Table 5.

According to the results of our two-year research, the most economically feasible was the cultivation of the DN Khortytsia hybrid, where the profitability level was 144.2–147.2 % and the net operating profit was 23,993–24,985 UAH/ha. The DN Slavytsia hybrid also showed good results over the two years of research, with a net operating profit of 22,393–22,816 UAH/ha and a profitability level of 134.4–134.6 %.

Table 5. Economic efficiency of growing maize hybrids of different maturity groups depending on the sowing dates, (2019–2020)

Hybrid	Sowing date	Yield, t/ha	Production expenses, UAH/ha	Cost of grain, UAH/t	Sales value, UAH/ha	Profit, UAH/ha	Profita-bility, %
DN Nur (FAO 150)	15 April	8.4	16641.0	2000.0	36641.0	20000.0	120.2
	24 April	8.7	16979.0	1976.0	37856.0	20877.0	122.9
	9 May	8.1	17030.0	2123.0	35354.0	18324.0	107.6
DN Khortytsia (FAO 240)	15 April	9.3	16641.0	1803.0	40634.0	23993.0	144.2
	24 April	9.6	16979.0	1781.0	41964.0	24985.0	147.2
	9 May	9.0	17030.0	1909.0	39337.0	22307.0	130.9
DN Slavytsia (FAO 270	15 April	8.9	16641.0	1876.0	39034.0	22393.0	134.6
	24 April	9.1	16979.0	1878.0	39795.0	22816.0	134.4
	9 May	8.7	17030.0	1975.0	37974.0	20944.0	129.7
DN Drah (FAO 340)	15 April	7.9	16641.0	2109.0	34699.0	18058.0	106.4
	24 April	8.2	16979.0	2101.0	35813.0	18834.0	111.9
	9 May	7.8	17030.0	2214.0	33865.0	16835.0	98.9

Conclusions. A two-year research has established the dependence between the grain yield of maize hybrids of different maturity groups and the sowing dates and weather conditions in the Western Forest-Steppe zone of Ukraine. It was found that the highest yield of maize in 2019–2020 was obtained by sowing on 15 April (soil temperature at the depth of seed placement was 8–10 °C) and 24 April (soil temperature at the depth of seed placement was 10–12 °C). In this case, the yield indicators were as follows: in the early-ripening hybrid DN Nur – 8.40–8.68 t/ha, in the mid-early hybrids DN Khortytsia and DN Slavytsia – 9.3–9.6 and 8.9–9.1 t/ha, respectively, and in the mid-ripening hybrid DN Drah – 7.9–8.2 t/ha.

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Ящук Т. С., Самець Н. П., Шубала Г. В., Сидорук Г. П. Ефективність строків сівби гібридів кукурудзи різних груп стиглості в умовах Західного Лісостепу України.

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***Актуальність**. Впродовж останніх десятиліть в аграрному бізнесі України кукурудза та соняшник стали стратегічними культурами, впливаючи на надходження валюти в країну і забезпечуючи левову частку прибутку сільськогосподарським виробникам. Сучасні гібриди кукурудзи мають значний генетичний потенціал для формування високих урожаїв, але їм необхідно створити належні умови для росту й розвитку рослин. Для досягнення цієї мети слід застосовувати заходи, які здатні оптимізувати умови вирощування кукурудзи на всіх етапах органогенезу. Важливого значення в умовах зміни клімату в сторону потепління набуває такий елемент технології, як строк сівби. Встановлено пряму залежність між ступенем розвитку рослин і строками сівби. **Мета.** Дослідити та виявити найбільш ефективні елементи технології вирощування кукурудзи в умовах Західного Лісостепу України. **Матеріали і методи.** Дослідження проводили на полях селекційної сівозміни Тернопільської державної сільськогосподарської дослідної станції Інституту сільського господарства Карпатського регіону НААН після пшениці озимої (на фоні $N_{60}P_{30}K_{30}$). **Результати.** В основу розробки покладено дослідження оптимальних строків сівби гібридів кукурудзи на зерно різних груп стиглості. Сівбу першого строку проводили за температури ґрунту на глибині загортання насіння 8–10 °С, другого строку – за 10–12 °С, третього – за 12–14 °С. Результати досліджень свідчать, що для умов Західного Лісостепу найбільш економічно виправданим є вирощування ранньостиглого гібрида ДН Хортиця, коли температура ґрунту прогрівається до 10–*

12 °С. Найвищу урожайність зерна (10,06 т/га) та економічну ефективність (рівень рентабельності 147,7 %) отримано при вирощуванні гібрида ДН Хортиця. ***Висновки.*** *Результати досліджень засвідчили, що сівба гібридів кукурудзи на зерно різних груп стиглості в оптимальні строки сприяє вирішенню таких проблем, як раціональне використання поживних речовин і вологи ґрунту, боротьба з бур'янами і шкідниками сільськогосподарських культур, поліпшення фізико-хімічних властивостей ґрунту, підвищення ефективності застосування добрив і техніки, здешевлення одержаної сільськогосподарської продукції.*

Ключові слова*: гібриди кукурудзи на зерно, елементи технології вирощування, температура ґрунту, структура урожаю, продуктивність, економічна ефективність*