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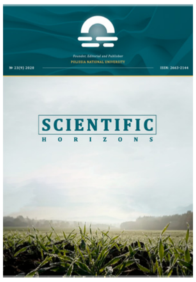

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Comparative analysis of the main economic and biological parameters of maize hybrids that determine their productivity

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Abstract. Corn kernels are characterised by the presence of all the nutrients, macro- and microelements necessary for growth and development in an easily digestible form. Considering the differentiation of soil and climatic zones of cultivation, the breeding process is designed to establish hybrids of different maturity groups. The research purposes to evaluate maize hybrids of different maturity groups for a set of economic and biological traits of productivity, high-yield stability, and further cultivation in production conditions suitable for mechanised harvesting. Methods used in the research include informational, theoretical analysis, synthesis, analogy, comparison and generalisation; research identification, and measurement. During the research, a systematic analysis was applied, considering the uniqueness of technical, productive, and economic conditions for growing hybrid corn. The research results demonstrate that to achieve successful regulation of maize hybrids productivity and improve their quality, it is necessary to select for suitability for specific soils and climatic zones, considering the biological requirements for seeds and developing effective agrotechnical means designed for processes occurring at different stages of growth and development. The seeds of corn hybrids, formed by breeding,

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were determined by a high nutrient content: In mid-early corn, the content of crude protein was 9.2-9.9%, crude fat – 4.2-4.4%, BER (nitrogen-free extractives) – 82.5-83.3%, starch – 71.4-73.7%; in the medium-late group, the content of crude protein ranged from 9.8-10.4%, crude fat from 4.1-4.6%, BER from 80.6-82.2%, and starch from 70.2-74.1%. The medium-early group of hybrids obtained the optimal height of 245-276 cm, the weight of 1000 seeds – 308-344 g, the ratio of node height to plant height – 0.445; the medium-ripening group respectively 296-351 cm, 318-382 g, 0.455

Keywords: seed quality; dry matter yield; yield; agroclimatic conditions; methods of quality determination

INTRODUCTION

Improving the agronomic characteristics of maize genotypes and management practices is essential for increasing the yields and profitability of agriculture. Successful management of corn seed productivity and quality requires careful selection of hybrids, considering soil, climatic and biological measures at different stages of growth and development.

I.V. Baskakov *et al*. (2020) characterise the optimal ratio of productivity and economic cost of cultivation, reporting that in the world about 20% of corn seeds are used for food production, 15-20% – for technological processing, 60-65% – for feed, compared to the percentage in the EU countries of 20%, 18% and 72%, respectively. V.V. Hlyva *et al*. (2022) report that the gross harvest of corn reaches 35.8 million tons, with an average yield of 7.84 t/ha.

X. Wang *et al*. (2019) prove that the development of corn biomass depends on the potential of a particular genotype and its combination with the combined effect of several factors, including hydrothermal conditions and technological methods designed to established high-protein forms. Following Z.A. Talukder *et al*. (2022) maize hybrids resulting from crossing genetically different parental forms have the following specific properties: high yield, high disease resistance, ability to rapidly accumulate moisture, improved chemical composition, biological characteristics that affect the quality of maize grain from the influence of seed rates, seeding depth, sowing time, and crop thickening. In the work of R. Fritsche-Neto *et al*. (2021) it is reported that parental forms are established by the self-pollination of maize lines in 6-8 generations.

W.S. Rezende *et al*. (2020) state that over the past 60 years, most corn has been produced from hybrid seeds derived from inbred strains bred as a result of generations of self-pollination and artificial selection. To increase the overall grain and feed yields, the Ukrainian agro-industry supports corn production by increasing the area under cultivation and rationalising using different hybrids depending on the length of the growing season. Ukraine's soil fertility and physical and climatic conditions are suitable for growing corn, which produces high-quality food in sufficient quantities to meet domestic needs and export potential.

The optimisation of production costs and exploring market conditions for agricultural products are prioritised. R.C. Schwartz *et al*. (2022) determined that given the intensification of agricultural production, it is advisable to explore the development of model technologies for growing crops in self-regenerating systems that are most suitable for the effective application of the laws of nature and the best use of bioclimatic resources, contributing to an increase in corn yields, preservation and improvement of soil fertility, and rational use of productive precipitation and moisture.

Ya.V. Byelov (2018) reports that in 2000, the world gross harvest of corn was 592 million tons, and using diversification of production and an increase of sown areas in 2019, the harvest reached 1148 million tons, outstripping rice and wheat. It is mainly caused by the global food crisis, which stimulated demand, thus, today corn accounts for a significant part of total grain production and is the main export crop of Ukraine.

Following O.M. Kolisnyk *et al*. (2020) corn yields can vary by up to 20% depending on the right choice of soil and climatic conditions for the hybrid in which the crop is grown. Almost 50% of the total seed yield is determined by the genotype of the hybrid, while only 30% and 20% are determined by growing conditions and climate. An appropriate supply of nutrients is essential for achieving high crop yields, as the intensity of mineral consumption depends on local soil and climatic conditions and the maturity of hybrids, etc. Corn forms a large germ mass, absorbing nutrients within a relatively short period from the intensive growth phase.

B.D. Kamenshchuk (2020) in his research, argues that due to climate differences, the requirements for hybrid composition and technology of corn cultivation are different. The climate in Ukraine is becoming less continental, and in winter it is more similar to the climate of Western Europe. It is evidenced by the fact that the center of atmospheric action that establishes Ukraine's climate has shifted by about 10° to the east. The agroclimatic conditions in the corn-growing areas are divided into three agroecological zones: Steppe, Forest-Steppe, and Polissya.

The research aims to evaluate maize hybrids of different maturity groups according to a set of economic and biological traits: productivity, suitability for mechanized harvesting, high stability, and yield for further cultivation in production conditions.

MATERIAL AND METHODS

Throughout the research, the following theoretical methods were used: information, analysis, synthesis, analogy, comparison, and generalisation; and research methods: identification – description of the main technological features of corn hybrids; measurement –

determination of morphological characteristics and constituent elements of the crop. A systematic approach was used in the study, considering the unique technical and economic conditions of the complexity of growing hybrid corn.

Following the methodology for the examination and state testing of plant varieties (Tkachyk *et al.,* 2016) biometric and morphological assessments of phenological observations were conducted to determine changes in the phases of growth and development, and periods of development of plant organs – leaves, stems, and cobs. The main area of maize hybrid breeding is designed to increase yields and product quality, resistance to diseases, pests, and adverse environmental conditions, such as drought resistance, cold resistance, and heat resistance, and establishing varieties suitable for cultivation using intensive technologies with full mechanisation of all processes. Depending on the agroecological conditions of corn hybrids of different maturity groups, different rates of plant growth and development are observed depending on the planting density. Following the systematised data of V.D. Buhayov *et al.* (2010) the main factors influencing the seed productivity of parental components represented by self-pollinated lines and simple interline hybrids with optimisation of agrotechnical measures, in particular: sowing time, plant density, and using modern drugs of biological origin, were established.

The conditions for growing productive maize hybrids are analysed: maturity, soil conditions, resistance to cold, drought tolerance, plant growth intensity and ability to suppress weeds, plant stunting, harvesting mechanisms, response to plant density, seed drying rate, and the usefulness of high-quality products, resistance to pests and diseases, male sterility, the profitability of seed production, and the periods of crop growth in terms of the emergence of seedlings, the flowering of panicles, cobs, and formation of milky, waxy, and full ripeness.

The maize hybrids were identified using morphological descriptive methods used to determine differences, uniformity and stability, field inspection, field and laboratory control of varieties: plant height, cob attachment height, node height to plant height ratio, cob length, number of rows of grains and seeds per row, total cob graininess. The weight of 1000 seeds were determined by weighing 500 seeds from the central zone of the tuber of one genotype by two separate weights with an accuracy of 0.01 g. If the difference between the weights of the selected samples exceeded 3%, another sample was taken and weighed.

The main breeding traits of maize hybrids were evaluated by the chemical composition of nutrients and moisture content. Laboratory studies were performed under generally accepted methods for conducting research in biology by V.V. Vlizlo *et al.* (2012) for the content of total Nitrogen converted to crude protein, crude fat, crude fiber, crude ash, BER (nitrogen-free extractives), and starch.

RESULTS

As energy costs rise, corn production is increasingly focused on resource-saving technologies and the role of hybrids as an important component of growing technology. Corn is grown using resource-saving and mechanised agricultural technologies with using early maturing hybrids. The growing season is one of the main features of genotypes and an indicator of the adaptive capacity of new source material to environmental conditions, which is used to determine corn hybrids in specific agroclimatic zones.

The early maturity and cold resistance of modern corn hybrids have become significant and economically valuable features of increasing the efficiency of corn production in the development of the grain balance of Ukraine. The advantages of growing early ripening hybrids allowed growing them together with late-ripening forms to slow down competition for moisture accumulation, provide sufficient light conditions, synthesise nutrients, gain flexibility in sowing dates, program the risks of yield reduction caused by early drought, and achieve full grain maturity when sowing dates are delayed. Late-ripening hybrids have higher productivity, but the use of early-ripening and mid-early hybrids allows for diversify the risks associated with weather events throughout the growing season and ensures that agrotechnical harvesting techniques are implemented at the optimal time. Modern early hybrids, under favorable temperatures, can catch up or slow down the developmental phases during periods of heat deficit (Fig. 1).

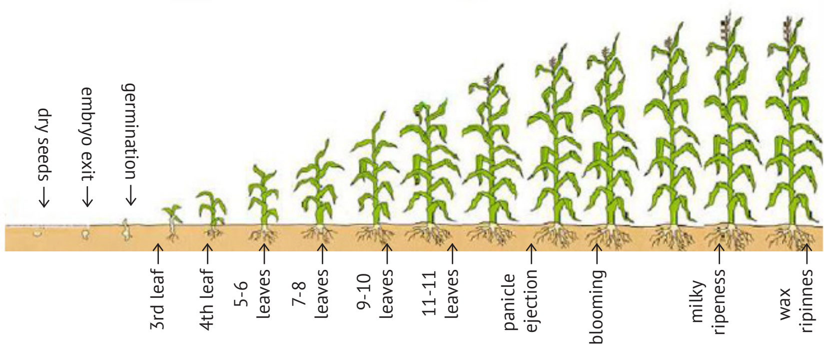

Figure 1. *Phenological phases of maize growth and development*
Note: *based on the author data (Rudavska & Hlyva, 2018)*

The length of the growing season in breeding practice is determined by such indicators as the number of leaves on the main stem, the number of veins on the leaf surface, the number of days from germination to the flowering of male and female inflorescences, the total effective temperature and moisture content of the grain. The International Food and Agricultural Organization (FAO) (2023) classifies maize hybrids by maturity and establishes the generally accepted FAO index, which is used to assess early maturity and compare grain hybrids by biological parameters, used in agronomy and plant breeding. The global range of maize hybrids is divided by FAO numbers in a wide range of 100-999, and the established units correspond to the values of average temperatures. The FAO classification of corn hybrids is described in detail in Table 1.

Table 1. *Classification of corn hybrids by FAO*

Early maturity group	FAO index	A sum of active temperatures, °C	A sum of effective temperatures, °C	Vegetation period, days	Leaves count, pcs
Early ripening	100-199	2200	900-1000	90-105	12-14
Average-early ripening	200-299	2400	1100	105-115	14-16
Average ripening	300-399	2600	1150	115-120	17-18
Average-late ripening	400-499	2800	1200	120-130	19-20
Late ripening	500-599	3000	1250-1300	135-140	21-23

Note: *based on the author data (Bahan et al., 2022)*

Top popular corn hybrids grew by leading agricultural holdings in Ukraine: Monsanto – (DKS 4014 (FAO 310), DKS 3511 (FAO 330), DKS 3939 (FAO 320), DKS 4590 (FAO 360), DKS 4351 (FAO 350), DK 315 (FAO 310), DKS 3730 (FAO 280), DKS 4541 (FAO 380), DKS 4408 (FAO 340); NAAS of Ukraine – DB Khotyn (FAO 250), DB Galatea (FAO 250), DB Khortytsia (FAO 240), DB Ajamka (FAO 320). LG Seeds – Adeway (FAO 290), LG30315 (FAO 280), LG30273 (FAO 260); KWS SAAT SE – KWS 2370 (FAO 280), Kerberos (FAO 310); Syngenta – Phenomenon (FAO 220), NK Cobalt (FAO 330), Maize Novy (FAO 330), Twist (FAO 270), Monica 350 MV (FAO 350); Euralis EU – Method (FAO 380); Universeed – EXPI 143 (FAO 320) (2023).

The duration of the growing season and physiological phases of maize plant development is significantly influenced by a set of factors such as plant genotype, place of cultivation, the sum of effective air temperatures, precipitation, and the level of cold resistance of the genotype. Corn is a short-day plant that does not tolerate shade, which leads to a delay in plant development and therefore a decrease in grain yields, even in excessively fertile crops. With 8-9 hours of daylight, corn grows faster, but a day length of 12-14 hours delays its maturation.

The characteristic climatic conditions are determined by the appearance of the next leaves in corn; seeds germinate best at a temperature of 8-10°C, seedlings appear at 10-12°C, and growth stops at 10°C and below. During the development of generative organs, the optimum temperature is 19-23°C, and the most favorable growth level is 25-30°C. During the flowering period, corn pollen contains up to 60% moisture, at temperatures above 30-35°C and relative humidity of 30%, the cobs quickly become weak, dry out within 1-2 hours, and subsequently lose their ability to germinate, in contrast to the temperature range of 18-19°C in cool climates. The development, filling, and ripening of corn kernels is possible at relatively low temperatures: the average daily temperature is 11-12°C, and the daytime temperature is 15°C. Seed filling and wax ripening occur faster at higher temperatures, while the interphase cycle increases significantly at temperatures below 14°C. Autumn frosts of 2-3°C damage plants and leaves. Corn can withstand spring frosts better than autumn frosts. Damaged seedlings will grow back within a week. Early varieties and hybrids can withstand low temperatures and frosts better than later ones. The total biologically active temperature required for the ripening of early-ripening varieties is 1800-2000°C, and for medium- and late-ripening varieties 2300-2600°C.

Favourable soil conditions lead to high yields in clean, ventilated areas with a deep humus layer, and soil fertility requires proper cultivation and fertilisation. The optimal reaction of the soil solution is neutral or slightly alkaline pH 5.5-7.0, while wet, acidic, heavy clay, saline and peaty soils (often lacking in copper ions) are not suitable for corn. A modern fertilisation system is impossible without diagnosing crops based on soil analysis. Higher corn yields cannot be achieved without NPK (Nitrogen, Phosphorus, Potassium) fertilisers. Increased yields per hectare and high absorption of macro- and microelements lead to a gradual decrease in their availability in the soil. A high level of consumption of the main elements is necessary to increase quantitative and qualitative productivity. For the production of 1 ton of corn grain with the appropriate amount of leaf mass, on average, 24-30 kg of Nitrogen, 10-12 kg of Phosphorus, and 25-30 kg of Potassium are injected into the soil. The development of corn grain yields at the level of 5.5-6.0 t/ha on average removes 132-180 kg of Nitrogen, 55-72 kg of Phosphorus, and 138-180 kg of Potassium from the soil.

Trace elements are essential for plant growth, but in much smaller amounts than the main nutrients such as Nitrogen, Phosphorus, Sulfur, and Potassium. Trace elements such as Ferrous, Zinc, and Manganese are important for corn nutrition. Ferrous is active in the redox reactions of plants, thus, about 75% of intracellular iron is bound in chloroplasts. The total amount of iron in the soil ranges from 200 to 100,000 mg/kg, but its solubility is negligible. Chlorophyll synthesis, cellular respiration, chemical reduction of nitrates and sulfates, and absorption of nitrogen – effectively affect the metabolism of nucleic acids, chloroplasts, and RNA (ribonucleic acid).

Considering the adaptive feature of maize hybrids, the flowering of panicles and cobs was observed on average in early maturing plants on the 40-45th day, and mid-season plants – on the 45-55th day with a time interval between flowering and panicle blooming of 3-6 days. A medium-sized panicle is 25-30 cm long and has 12-18 branches and a high pollen production capacity. The period from flowering to ripening in many samples exceeds 50 days. By length, the main stem hybrids are divided into low 15%, medium 15%, and high 70%.

Table 2 demonstrates the levels of economic and biological traits of maize hybrids according to important factors: number of cobs per plant, multi-row seeding per cob, number of seeds per row, the total number of seeds per cob, and weight of 1000 seeds.

Table 2. *The level of economic and biological traits of maize hybrids*

Trait	Trait character level		
	medium	**minimal**	**maximum**
The number of days from germination to:			
flowering cob	75	44	101
full maturity	136	127	146
Crop height, cm	313	256	371
Head attachment height, cm	146	97	217
Cob length, cm	17	11	25
Seed row amount, pcs	14	6	17
Amount of seeds in a row, pcs	29	10	48
The total amount of seeds in a cob, pcs	407	60	672
Weight of 1000 seeds, grams	418	340	576

Note: *based on the author data (Marchenko et al., 2021)*

Yield is the main trait that best reflects the biological characteristics of hybrids and their response to growing conditions. According to the annual monitoring of Monsanto Ukraine, in 2022, the best hybrid was DKC 3705, which at a standard moisture content of 14% yielded 12.5 t/ha, DKC 4590 – 12.36 t/ha, DKC 4014 – 12.31 t/ha. Table 3 demonstrates the agronomic characteristics of DKC corn hybrids used for intensive technologies.

Table 3. *Agronomic characteristics of DKC corn hybrids*

Trait	DKC 3705	DKC 4590	DKC 4014
Maturity group	**medium maturity**	**medium maturity**	**medium maturity**
FAO	320	360	310
Purpose	for seeds	for seeds	for seeds, silos
Seed type	toothed	toothed	toothed
Crop height	210-250	240-270	220-235
Number of rows	14-18	16-20	14-16
Amount of seeds in a row	40-46	37-42	35-42
Starch contents	73%	more than 72%	more than 72%
Weight of 1000 seeds	310-360	280-350	280-350
Yield potential	15 t/ha	15 t/ha	15 t/ha
Drought resistance	9	9	9
Resistance to lodging	8	8	9

Table 3, Continued

Trait	DKC 3705	DKC 4590	DKC 4014
Maturity group	**medium maturity**	**medium maturity**	**medium maturity**
Resistance to helminthiasis	9	8	9
Resistance to smut	9	9	9
Resistance to fusarium	8	8	8

Note*: Based on the source data (All phases of corn development..., 2017)*

The growth and development of maize hybrids reflect a complex process of interaction between genotype and environmental factors, thus, the assessment of plants in ontogeny will provide opportunities to reveal the most important dependencies in the development of high productivity. The complex parameters of new maize hybrids, including morphological and biometric assessment of plant vegetative organs, are an important economically valuable indicator, as presented in Table 4.

Table 4. *Characterisation of the examined maize hybrids by economic and biological traits*

Hybrid name	flowering cob	full maturity	Crop height, cm	Head attachment height, cm	Cob length, cm	Seed row amount, pcs	Amount of seeds in a row, pcs	The total amount of seeds in a cob, pcs	Weight of 1000 seeds, grams	Moisture, %
Medium early (FAO 200-299) seeding rate, 80 thousand seed germination per 1 ha										
DB Khotyn (FAO 250)	68	113	245	88	23	38	18	223	308	19.9
Gran 310 (FAO 250)	61	117	276	95	18	28	16	250	326	19.4
Leleka (FAO 250)	65	122	271	92	22	40	17	284	344	19.9
Medium late (FAO 300-399) seeding rate, 75 thousand seed germination per 1 ha										
SI Orpheus (FAO 360)	75	136	296	99	19	45	17	239	318	20.1
Monica 350 MV (FAO 350)	68	147	300	107	18	37	18	245	355	20.6
Roziv 311 CB (FAO 310)	71	146	351	102	20	38	17	276	382	20.5

Note: *Based on our research*

The ratio of the height of corn hybrids by maturity groups and yield level demonstrated that for the mid-early group (FAO 200-299), in the phase of termination of linear growth, the optimal height of plants is 245-276 cm and the weight of 1000 seeds is 308-344 g, with an average ratio of node height to a plant height of 0.445; for the medium-ripening group (FAO 300-399), the plant height is 296-351 cm, with a weight of 1000 seeds of 318-382 g, the ratio of node height to plant height is 0.455. Laboratory studies have established the content of the main nutrients in the grain of corn hybrids, which is presented in detail in Table 5.

Table 5. *Chemical composition of corn hybrids under study, %*

Hybrid name	raw protein	raw fat	raw fiber	raw ash	nitrogen-free extractives	starch
Medium early (FAO 200-299) seeding rate, 80 thousand seed germination per 1 ha						
DB Khotyn (FAO 250)	9.24	4.25	2.11	1.12	83.28	71.43
Gran 310 (FAO 250)	9.51	4.44	2.32	1.21	82.59	73.74
Leleka (FAO 250)	9.88	4.22	2.29	1.18	82.51	72.21
Medium late (FAO 300-399) seeding rate, 80 thousand seed germination per 1 ha						
SI Orpheus (FAO 360)	10.12	4.54	3.12	1.65	80.57	74.12
Monica 350 MV (FAO 350)	10.32	4.28	2.56	1.23	81.61	70.23
Roziv 311 CB (FAO 310)	9.76	4.12	2.73	1.16	82.23	73.12

Note: *Based on our research*

In medium early maize hybrids, the content of crude protein was at the level of 9.2-9.9%, crude fat – 4.2-4.4%, crude fiber – 2.1-2.4%, BER – 82.5-83.3%, starch – 71.4-73.7%. In medium-late maize hybrids, the content of crude protein was at the level of 9.8-10.4%, crude fat – 4.1-4.6%, crude fiber – 2.6-3.1%, BER – 80.6-82.2%, starch – 70.2-74.1%. Indicators of the actual content of nutrients provide reliable information about the amount but do not guarantee full digestibility in the body of animals.

DISCUSSION

The yield and quality of corn grain are the results of the interaction of genetic, environmental, and agronomic factors as one of the most productive and versatile grains in the world, which is grown for food, feed, and various technological processes. The total corn harvest in Ukraine's agro-industrial complex is increasing due to the growth of sown areas and the rational use of hybrid varieties depending on the length of the growing season. The most popular and versatile are mid-season hybrids with FAO indices of 280-390. The length of the growing season in breeding practice is determined by such indicators as the number of leaves on the main stem, the number of veins on the leaf surface, the number of days from germination to the flowering of male and female inflorescences, the total effective temperature and moisture content of the grain.

The height of the hybrids and the number of leaves on the corn stalks indicate that the activation of growth processes occurs in the early stages of growth and development. According to V. Palamarchuk and N. Telekalo (2018) it was found that early and mid-season varieties do not present significant changes in yield due to late sowing, while late varieties have a better chance of implementing their genetic potential with early sowing when the soil temperature reaches +8-10°C. Therewith, sowing in these terms leads to a decrease in grain moisture content at harvest for all biotypes. When sowing early, it is necessary to consider the degree of cold resistance of hybrids and apply appropriate technical measures to protect the seeds during preparation, with the mandatory treatment of seeds with complex preparations of fungicides, trace elements, and growth regulators. The photosynthetic potential of the leaf surface of maize hybrids is an important factor in establishing a total biological yield, characterised by the total leaf surface, growth rate, and time of active activity during the synthesis of generative organs of plants. M.R. Nunes *et al.* (2020) states that as the range of high-yielding early and medium-early maize hybrids increases, it is recommended to increase their share in total crops to 15-20% and 30-35%, respectively, and to sow 40% and 10% of the sown areas with medium and late forms, respectively. Corn hybrids with a short vegetation period shift the stages of morphogenesis to an earlier period, thus, early maturing hybrids have critical periods of development, such as panicle ejection, flowering, pollination, grain filling, avoiding arid abnormal temperatures, passing the established deadlines in relatively better conditions.

The precise identification of the physiological and molecular biological mechanisms underlying tolerance, which is defined by the ability of plants to cope with damage-induced stress, will be useful for the control of existing maize germplasm collections. This issue will become increasingly important as agriculture becomes more mechanised. In his work A.W. Abubakar *et al.* (2019) compare the study of physiological and biochemical characteristics of maize hybrids of different maturity groups, determines the productivity of plants of a certain genotype by the ability to synthesize nutrients, form a larger assimilation surface, establish a favourable ratio between assimilation and dissimilation, and have high resistance to adverse environmental factors.

Following U. Rosskopf *et al.* (2022) when sowing corn, the depth of planting depends largely on the physical and mechanical properties of the soil, moisture content, and temperature. The optimal planting depth for corn is 4-5 cm in heavy clay soils, 5-6 cm in light clay soils, 5-7 cm in black soil, and 6-8 cm in sandy loam soils. As the topsoil dries, the planting depth should be increased by 1-2 cm.

M.V. Kapustyan *et al.* (2021) states that the factors of maturity, sowing time, sowing density of maize, and favourable environmental conditions affect changes in the level of productivity and morphological and biological characteristics of plants, but the greater factor is the dependence on genotype. Since genotypes demonstrate different levels of phenotype expression under the influence of environmental conditions, significant genotype-environment interactions occur under stress conditions, thus, damage to parts that act as abiotic stress to the plant, causing significant seed losses, especially in less favourable years of maize growth, when there is a variation in seed losses between breeding races.

Breeding efforts to develop high-protein corn hybrids play an important role in improving quality. Y. Beyene *et al.* (2019) in his research, used the process of selective mutations of the o2 and fl2 genes, which led to the inhibition of gelatin synthesis, increase of glutelin and lysine-protein fractions, increasing the level of protein and lysine protein by 14-16% compared to conventional strains.

Photosynthetic productivity is not a constant process, it changes under the influence of many factors. Current global climate trends make it particularly important to increase the cultivation of drought and heat-tolerant maize. Climate models predict more frequent and severe extreme weather events with serious consequences for crop yields and, indirectly, for food security. The impact of climatic parameters such as water availability and temperature have been identified as important factors affecting maize productivity, for example, rainfall in April-August has a greater impact on yield than nitrogen fertilisation. Corn is more sensitive to drought during pollination and grain filling, thus, under the influence of the continental climate, it is a significant abiotic regulator of grain yield. Reducing the impact of environmental conditions is determined by the accuracy of cob removal, with a minimum of damage to crops in unfavorable years.

Among many agrotechnical practices, fertilisation is of paramount importance, affecting the growth, development, and productivity of hybrid corn. L.P. Telychko (2020) proves that when growing corn for grain, the most important nutritional factor is not the number of nutrients supplied with fertilisers, but their ratio. Balanced nutrition helps to avoid prolongation of the second half of the growing season and to harvest at the optimal time. The maximum nitrogen consumption by corn begins during the pollen release period and continues until the milk wax ripens. Lack of nitrogen in the soil delays plant growth and reduces the intensity of photosynthesis and protein metabolism.

Technological methods studied in works A.B. Ghețe *et al.* (2020) have different effects on the photosynthetic productivity of maize crops, thus, the introduction of nitrogen-phosphorus and full mineral complexes allows increasing crops by 27.7% and 22.9%, respectively, compared to the background of natural soil fertility. The balanced supply of plants with essential macro- and microelements occurs not only during the period of pre-sowing soil cultivation with fertilisers. Micronutrients can be absorbed much more actively by the leaf surface of corn hybrids than by the root system of plants, thus, an effective way to meet their needs is to foliar feed crops with micro fertilisers. The main advantage of organic products is increased growth energy, which leads to a rapid increase in corn biomass and improved competitiveness.

The growing season of modern corn hybrids grown in Ukraine ranges from 90 to 150 days. S.V. Filonenko (2013) cites the following parameters of the duration of the growing season and the number of leaves on the main stem of corn: early ripening – 90-100 days of vegetation and 14-15 leaves; medium early – 105-115 days and 15-16 leaves; medium ripening – 115-120 days and 17-18 leaves; medium ripening – 120-130 days and 18-19 leaves; late-ripening – 135-140 days of vegetation and 19-20 leaves. In mid-early hybrids, the second half of the growing season is shorter than the first, but both periods should be the same for hybrids grown in the mid-early and mid-late periods, and longer for hybrids grown in the mid-late period. Subject to optimal corn sowing technology and optimal sowing dates, early hybrids ripen in late August, while mid-season hybrids ripen in the first and second half of September-October.

CONCLUSIONS

Based on the experimental studies, the expression and variability of productivity factors by the periods of ripeness of hybrids of the medium early and medium late groups were determined. It was found that the length of the growing season affects the height of plants, thus, the tallest hybrids and the height of the cob attachment belong to the medium-late group. The optimum height of medium early maize was noted at 245-276 cm, the weight of 1000 seeds 308-344 g, node height/plant height ratio 0.445 and, respectively, 296-351 cm, 318-382 g, and 0.455, which were obtained in the medium late group of hybrids.

Hybrid maize is characterised by its chemical composition of grain, high content of starch, protein, and nitrogen-free extractives, being a necessary raw material in the food industry and production of concentrated feed. In the mid-early corn group, crude protein was 9.2-9.9%, crude fat was 4.2-4.4%, crude fiber was 2.1-2.4%, BER was 82.5-83.3%, and starch was 71.4-73.7%. In the medium-late groups, crude protein ranged from 9.8-10.4%, crude fat – 4.1-4.6%, crude fiber – 2.6-3.1%, BER – 80.6-82.2%, and starch – 70.2-74.1%. The level of moisture transfer depended on the biological characteristics of maize hybrids of different maturity groups, thus, the percentage of seed moisture was 19.4% in the medium early group and 20.6% in the medium late group.

The scientific task of substantiating priority measures for the competitive production of productive hybrids under modern economic conditions was theoretically generalised and solved, the optimal parameters of plant density, sowing time, effective and rational use of biologically active preparations, levels of mineral nutrition of corn with the introduction of complex micro-fertilisers and growth stimulants were established.

In the future, to obtain high-quality and homogeneous seed material, it is recommended to explore seeding rates and resistance to pests and diseases of corn hybrids, fully unlocking the genetic potential and contributing to the economic profitability of growing the crop.

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CONFLICT OF INTEREST

The authors declare no conflict of interest.

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Порівняльний аналіз основних господарсько-біологічних показників гібридів кукурудзи, що визначають їх продуктивність

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Анотація. Зерно кукурудзи характеризується наявністю всіх необхідних для росту і розвитку поживних речовин, макро- і мікроелементів у легкозасвоюваній формі. Враховуючи диференціацію ґрунтово-кліматичних зон вирощування, селекційний процес спрямований на створення гібридів різних груп стиглості. Метою досліджень є оцінка гібридів кукурудзи різних груп стиглості за комплексом господарсько-біологічних ознак продуктивності, стабільності високого рівня врожайності та подальшого вирощування у виробничих умовах, придатних для механізованого збирання. Методи дослідження: інформаційний, теоретичний аналіз, синтез, аналогія, порівняння та узагальнення; наукова ідентифікація, вимірювання. Під час проведення досліджень застосовано системний аналіз, який враховує унікальність технічних, виробничих та економічних умов вирощування гібридів кукурудзи. Результати досліджень свідчать, що для успішного регулювання продуктивності гібридів кукурудзи та підвищення їх якості необхідно проводити добір на придатність до конкретних ґрунтово-кліматичних зон, враховуючи біологічні вимоги до насіння та розробляючи ефективні агротехнічні засоби, розраховані на процеси, що відбуваються на різних етапах росту і розвитку. Насіння гібридів кукурудзи, створених селекційним шляхом, визначалося високим вмістом поживних речовин: У середньоранньої кукурудзи вміст сирого протеїну становив 9,2-9,9 %, сирого жиру – 4,2-4,4 %, БЕР (безазотистих екстрактивних речовин) – 82,5-83,3 %, крохмалю – 71,4-73,7 %; у середньопізньої групи вміст сирого протеїну коливався в межах 9,8-10,4 %, сирого жиру - 4,1-4,6%, БЕР – 80,6-82,2 %, крохмалю – 70,2-74,1 %. У середньоранній групі гібридів отримано оптимальну висоту 245-276 см, масу 1000 насінин – 308-344 г, відношення висоти вузла до висоти рослини – 0,445; у середньостиглій групі відповідно 296-351 см, 318-382 г, 0,455

Ключові слова: якість насіння; вихід сухої речовини; урожайність; агрокліматичні умови; методи визначення якості