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Svitlana Kalenska[1], Olena Kashtanova[2], Viktor Kalenskyi[1], Roman Hovenko[1*], Tetiana Antal[1]

[1]National University of Life and Environmental Sciences of Ukraine
03041, 15 Heroiv Oborony Str., Kyiv, Ukraine

[2]Anhalt University of Applied Sciences
06366, 55 Bernburger Str., Koethen, Germany

Economic and Energy Efficiency of Technologies for Growing Maize Hybrids Depending on the Type and Methods of Applying Fertilisers

Abstract. The urgency of solving the problem of the growth of maize grain production is unconditional, considering the needs of humanity, the economic, and energy efficiency of cultivation technologies, which substantially depends on the types of fertilisers and the frequency of their application. The purpose of this study was to prove the efficiency of maize grain production by perfecting the fertilisation system. Field research was conducted at the "Bohatyrivske" farm in the Romen district of the Sumy Oblast during 2019-2021 on dark grey podsolised soil. Mathematical and statistical processing was performed using the software package SAS 9.4 and "Agrostat 6". The economic and energy evaluation of technologies was performed using the calculation method. Hybrids are flexible to growing conditions, respond positively to nutrition optimisation – yield varies from 6.07-6.16 in the control to 8.26-8.50 t/ha with carbomidoammonium nitrate 32 on the background of $N_{22}P_{57}K_{57}$. With the background application of $N_{22}P_{57}K_{57}$, the yield increased by 16.4%. Nitrogen fertilisers over the background provided an added increase in yield by 7.95-18.6%. With the introduction of carbomidoammonium nitrate 32, the yield increase was 2.19 t/ha and 2.44 t/ha or 36.1% and 38.0%, respectively, of the Concord and Asteroid hybrids. The reaction of hybrids to ammonia water and urea is lower compared to carbomidoammonium nitrate. Production costs for growing maize amounted to UAH 20.3-32.3 thous./ha. The introduction of carbomidoammonium nitrate against the background of $N_{22}P_{57}K_{57}$ provided a high conditionally net profit – UAH 19.2-19.9 thous./ha. The profitability of maize grain production is quite high – 44-80%. With the addition of Humilin Stimul, the yield increases by 0.23-1.71 t/ha, depending on the combination of fertilisers. With all types of fertilisers, the highest efficiency was obtained with one-time feeding on BBCH 15-17. The coefficient of energy efficiency for the application of fertilisers decreases. The results of this study are important for production and further areas of research, namely the biodiversity of soil microflora

Keywords: grain market, yield, production costs, conditional net profit, profitability

INTRODUCTION

The global political crisis sets back the global grain market [1]. Soaring prices for energy resources lead to higher prices for fuel, electricity, fertilisers, plant protection products, and other material and technical resources. This increases the cost of production of agricultural products and may reduce the volume of its production in 2022. According to the forecast of the Food and Agriculture Organisation of the United Nations (FAO) [2] the world grain production in the 2021/2022 marketing year will amount to almost 2791.3 million tonnes, which will exceed the estimated data for the previous marketing year by 19.3 million tonnes (0.7%) [1; 3].

World grain production in 2020/21 was 2,772 million tonnes, production forecast for 2021/22 is 2,791.3 million tonnes, and consumption is 2,809.6 million tonnes. That is, consumption exceeds forecasted production. According to preliminary FAO forecasts [2; 4], it was assumed that

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*Corresponding author

in Ukraine in 2021/22 marketing year, grain production was to increase by 26.6% to 81.8 million tonnes due to a fairly significant increase in the production of maize, wheat, and barley [1; 4].

Maize, in terms of production and consumption, ranked first in the world among grain crops. It is predicted that in 2021/2022, the world maize production will be about 1.2 billion tonnes [5]. In 2020/21, the largest producer of maize in the world was the United States with almost 384 million tonnes, or a third of nominal world maize production. The largest maize producers in the world in 2019/20 were as follows: USA (31.1%); China (23.4%); Brazil (9.07%); EU (6%); Argentina (4.5%); Ukraine (3.2%); India (2.6%); Mexico (2.25%); South Africa (1.46%) and 16.5% – other countries [6; 7].

In 2020/2021, the United States exported over 61.5 million tonnes of maize, a third of total global maize exports. The largest consumers of maize in the world in 2020/21 were the following countries: USA – 12.0 billion bushels; China – 11.3; EU-27 – 3.13; Brazil – 2.77; Mexico – 1.73; India – 1.11; Egypt – 0.67; Japan – 0.63; Vietnam – 0.61; Argentina – 0.59 billion bushels. The total consumption in the world was 45.4 billion bushels [8].

The 2014-2020 global average maize grain price ranged from $193 per tonne in 2014 to $155 per tonne in 2017. However, in 2021, the price rose to $250 per tonne and the tendency for the price to rise or stay at this level persists [9].

The effectiveness of agricultural crop cultivation technology is dictated both by the absolute productivity and the economic efficiency of the cultivation technology, and by the implementation of certain technological innovations [10; 11].

Maize is an intensive crop, which, to form a high yield, requires considerable production costs, by which it often exceeds other grain crops [12]. Under changing climatic conditions and growing technologies, the adaptability of maize hybrids plays a critical role [13-15]. Maize effectively responds to the optimisation of plant nutrition due to increased yield [16; 17].

The economic basis of modern crop production is the balanced production with the best ratio of material and energy costs and the assessment of the gross output of products. The main indicators of economic efficiency include gross production costs, evaluation of the received gross products, profit, production prime cost, production profitability, general structure of costs [18]. Furthermore, modern cultivation technologies must be competitive in the technology market [19].

At the current stage, a feature of the agriculture development is that a 2-3-fold increase in yield is accompanied by a several-fold increase in the cost of non-renewable energy per unit of production. This gives reason to consider the production of plant products as an energy problem [20; 21].

Each technology involves different energy costs. To assess the practicality of a technological process or its individual methods from an energy perspective, it is necessary to assess their bioenergy efficiency quantitatively [22]. The final indicators of the bioenergetic assessment of maize cultivation technology include the gross energy costs, the energy intensity of the crop, and the energy efficiency coefficient.

The purpose of this study was to prove the economic and energy efficiency of maize cultivation technologies using diverse types of fertilisers and the frequency of fertiliser application.

MATERIALS AND METHODS

The study was performed by setting up and conducting field and laboratory experiments, followed by calculations of the economic and energy efficiency of cultivation technologies. The latter differed in terms of types, doses, and methods of applying fertilisers. Field research was conducted in 2019-2021 at the "Bohatyrivske" farm of Romen district of Sumy Oblast, in the northern part of the Left Bank Forest Steppe. The study was designed per the requirements of the methodology of the research case [23; 24] according to the method of split sections on dark grey podzolised soil. The degree of providing the soil with mobile forms of phosphorus, potassium, and nitrogen was as follows: phosphorus – 50-100 mg/kg; potassium – 40-80 mg/kg according to Chirikov, and nitrogen – 40-50 mg/kg according to Tiurin-Kononova [23].

To develop the elements of maize cultivation technology, namely the optimisation of maize fertilisation, in Experiment 1, the effectiveness of diverse types of fertilisers was investigated at the same rate of nitrogen application according to the active substance (N_{120}) on the background of $N_{22}P_{57}K_{57}$ per the developed scheme (Table 1).

Table 1. Scheme of the Experiment 1

Factor A Hybrid		Factor B Fertilisers		
Variant designation	Hybrid	Variant designation	Norm, kg/ha a.s.	Fertiliser
A1	ES Concord	B1	Control (without fertilisers)	
A2	ES Asteroid	B2	$N_{22}P_{57}K_{57}$ –background (B)	DAP
		B3	B+N_{120}	Ammonium water
		B4	B+N_{120}	UAM
		B5	B+N_{120}	Urea

The Experiment 2 was set up to establish the efficiency of maize cultivation with the combined use of nitrogen fertiliser types (ammonia water, UAM 32 fertiliser, and urea) and, against their background, of the Humilin Stimul preparation in foliar feeding (Table 2). Humilin Stimul was fed once and twice in microstages BBCH 15-17 and BBCH 17-19. The preparation consumption rate was 3 l/ha.

Table 2. Scheme of the Experiment 2

Factor A Type of background fertiliser[1]		Factor B Humilin Stimul nutrition	
Variant designation	Fertiliser	Variant designation	Microstage, BBCH scale
A1	$N_{22}P_{57}K_{57}$ –background (B)	B1	–
A2	B+Ammonium water	B2	15-17
		B3	17-19
		B4	15-17 and 17-19
A3	B+UAM	B5	15-17
		B6	17-19
		B7	15-17 and 17-19
A4	B+Urea	B8	15-17
		B9	17-19
		B10	15-17 and 17-19

The water-soluble complex fertiliser Humilin Stimul contains potassium humate (in terms of humic acids) – at least 40 g/l, succinic acid – 3 g/l, trace elements, other biologically active elements (gibberellins, auxins, cytokinins). The study was conducted with two hybrids (factor C) – ES Concord and ES Asteroid. The area of the accounting plot in the field experiment was 50 m^2, repetition was fourfold. Field studies were conducted with mid-ripening hybrids ES Concord (FAO 250) and ES Asteroid (FAO 290). Maize was sown when the soil was warmed up to 8°C: in 2019 – on April 15; in 2020 – on April 19; in 2021 – on April 23. Harvesting was performed in sections by continuous threshing. Before harvesting, plants were sampled to determine the biological productivity and structure of the crop.

The SAS 9.4 software package and the "Agrostat 6" computer program were used for mathematical and statistical processing of data from field experiments, namely on the yield. Indicators of economic efficiency were calculated at the prices of 2021 [6; 7]. The main criterion for the energy evaluation of maize cultivation was the energy efficiency coefficient (C_{ee}). This is the ratio of the gross energy obtained with the crop to the gross energy of all technological operations and raw materials spent.

RESULTS AND DISCUSSION

According to the results of field research, it was found that the maize hybrids under study are quite flexible to the growing conditions, respond positively to the optimisation of the provision of nutrients and form yield, which differed little between hybrids, and the tendency of the reaction of hybrids to types of fertilisers was similar. The range of yield changes on average for 2019-2021 for the ES Concord hybrid was from 6.07 t/ha in the control version to 8.26 t/ha with the use of UAM 32 fertiliser at N_{120} kg/ha a.s. against the $N_{22}P_{57}K_{57}$ background – DAP, ES Asteroid – from 6.16 t/ha to 8.50 t/ha, respectively (Table 3).

Table 3. Economic efficiency of growing ES Concord and ES Asteroid maize hybrids depending on the types of fertilisers, average for 2019-2021 (Experiment 1)

Variant[1]	Y[2]	Yield increase				Cost of gross products	Production costs	Conditionally net profit	Profitability
	t/ha[3]	to control		to background					
		t/ha	%	t/ha	%	UAH thous./ha			%
ES Concord (A1)									
B1	6.07[a]	–	–	–	–	36.4	20.3	16.1	80
B2	7.06[b]	0.99	16.3	–	–	42.4	25.1	17.3	69
B3	7.67[c]	1.60	26.4	0.61	8.64	46.0	31.8	14.3	45
B4	8.26[d]	2.19	36.1	1.20	17.0	49.6	30.4	19.2	63
B5	7.74[c]	1.67	27.5	0.68	9.63	46.4	29.2	17.3	59

Table 2, Continued

Variant[1]	Y[2]	Yield increase				Cost of gross products	Production costs	Conditionally net profit	Profitability
	t/ha[3]	to control		to background		UAH thous./ha			%
		t/ha	%	t/ha	%				
ES Asteroid (A2)									
B1	6.16[a]	–	–	–	–	36.9	20.8	16.1	78
B2	7.17[b]	1.01	16.4	–	–	43.0	25.7	17.4	68
B3	7.74[c]	1.58	25.7	0.57	7.95	46.4	32.3	14.2	44
B4	8.50[d]	2.44	38.0	1.33	18.6	51.0	31.1	19.9	64
B5	7.96[c]	1.80	29.2	0.79	11.0	47.8	29.9	17.8	59
LSD	0.44								

Note: [1] the content of the variant in Table 1; [2]Y – yield; [3] substantial differences between values if indicated by different letters, SAS 9.4

The calculations of the economic efficiency of technologies show that the gross technological costs for the cultivation of maize hybrids differed substantially and ranged from 20.3 thousand UAH/ha in the control version to 32.3 thousand UAH/ha upon the introduction of UAM 32.

Calculations of the economic and energy efficiency of carrying out added fertilisation of crops with Humilin Stimul fertiliser allowed finding effective combinations of fertilisers and Humilin Stimul feeding. The scheme of the experiment made provision for the establishment of the effectiveness of the joint application of a nitrogen fertiliser and Humilin Stimul feeding against the general background ($N_{22}P_{57}K_{57}$). Upon feeding with Humilin Stimul, the yield increased by 0.23-1.71 t/ha, depending on the combination of fertilisers (Table 4). It was proved that with all fertilisers under study, the highest effect was obtained with a one-time feeding in the BBCH 15-17 microstage (A2B2; A3B6; A4B9).

Table 4. Economic efficiency of growing maize hybrids using different nitrogen fertilisers and Humilin Stimul feeding, average for 2019-2021 (Experiment 2)

Variant designation[1]	Yield[2]	Yield increase		Cost of gross products	Production costs	Conditionally net profit	Profitability
	t/ha	t/ha	%	UAH thous./ha			%
ES Asteroid							
A1B1	7.16 [a]	–	–	42.9	25.3	17.6	70
A2B2	7.99[c]	0.83	11.6	47.9	29.9	18.0	60
A2B3	7.46[b]	0.30	4.19	44.8	29.1	15.7	54
A2B4	7.81[c]	0.65	9.08	46.9	29.9	16.9	56
A3B5	8.87[e]	1.71	23.9	53.2	28.9	24.2	84
A3B6	7.99[c]	0.83	11.6	47.9	27.6	20.3	73
A3B7	8.32[d]	1.16	16.2	49.9	28.5	21.5	75
A4B8	8.37[d]	1.21	16.9	50.2	27.9	22.4	80
A4B9	7.94[c]	0.78	10.9	47.6	27.2	20.4	75
A4B10	8.14[cd]	0.98	13.7	48.8	27.8	21.0	75
ES Concord							
A1B1	7.06[a]	–	–	42.4	25.1	17.3	69
A2B2	7.77[c]	0.71	10.1	46.6	29.2	17.4	60
A2B3	7.29[a]	0.23	3.26	43.7	28.5	15.3	54
A2B4	7.58[b]	0.52	7.37	45.5	29.2	16.3	56
A3B5	8.56[de]	1.50	21.3	51.4	28.1	23.6	83
A3B6	8.03[c]	0.97	13.7	48.2	27.3	20.9	77
A3B7	8.26[d]	1.20	17.0	49.6	27.9	21.6	77
A4B8	8.33[d]	1.27	18.0	50.0	27.4	22.6	82
A4B9	7.72[c]	0.66	9.35	46.3	26.5	19.8	75
A4B10	7.97[c]	0.91	12.9	47.8	27.2	20.6	76
LSD_{095}	0.41						

Note: [1]Designation of variants in Table 2. [2]The difference is substantial for values indicated with different letters, SAS 9.4

When evaluating the effectiveness of technologies for growing agricultural crops in modern conditions, it is advisable to consider not the absolute yield, but a balanced ratio of the cost of the technology and the cost of the obtained products. Record harvests are rarely economically justified [10; 20]. Considering the strong positive response of maize to fertilisers, it is necessary to economically justify the effectiveness of fertilisers and establish the feasibility threshold [19]. This means not only the determination of the break-even point, but the economic expediency itself [18].

The use of new-generation fertilisers with macro- and microelement composition, nanofertilisers, and long-acting fertilisers ensures targeted use of nutrients by plants [25-27]. The increase in maize yield is closely correlated with the rate of nitrogen fertilisers, and their effectiveness increases with the joint use of nitrogen fertilisers and urease inhibitors, biological preparations that reduce the direct dependence on nitrogen fertiliser rates [28]. Fertilisers of biological origin and those obtained via secondary processing are widely used in production and require scientific justification of their effectiveness [29]. Fertiliser with the proposed mechanism of action can be successfully used to feed maize plants grown in areas with cyclic moisture deficit. Optimisation of plant nutrition is closely related to the preservation of soil fertility, microbiological biodiversity, and environmental safety [30; 31].

The potential fertility of the soils on which the study was conducted is quite high. The yield in the control variants in Experiment 1 – without fertilisers, in Experiment 2 on the background of $N_{22}P_{57}K_{57}$ – without fertilising crops, where fertilisers were not applied, was formed at a relatively high level – 6.07 t/ha and 6.16 t/ha, respectively, for the ES Concord and ES Asteroid hybrids. Application of $N_{22}P_{57}K_{57}$ in the form of DAP, based on the active substance, ensured an increase in yield by 0.99-1.01 t/ha or 16.4%. Added application of nitrogen fertilisers against the background of application of DAP provided an added increase in yield from 0.57% to 1.33%, or by 7.95-18.6%. With the introduction of UAM 32, the yield increase of the ES Concord hybrid was 2.19 t/ha or 36.1%; ES Asteroid hybrid – 2.44 t/ha or 38.0%, compared to the control variant. The reaction of hybrids to the introduction of ammonia water and urea, which was determined by the increase in productivity, was lower compared to the introduction of UAM 32 (Table 3).

The economic efficiency of cultivation technologies is dictated by the ratio of gross technological costs to the cost of gross products. The calculation of the economic efficiency confirmed that the fertilisation system is one of the most expensive items in the growing technology – costs ranged from 20.3 to 32.3 thous. UAH/ha depending on the types of fertilisers. The introduction of UAM 32 on the background of $N_{22}P_{57}K_{57}$ (A1B4; A2B4) contributed to a high yield of hybrids, which ensured a high conditional net profit – 19.9 and 19.2 thous. UAH/ha, respectively, for the ES Asteroid and ES Concord hybrids. Added costs associated with the application of nitrogen fertilisers were paid off by a surplus harvest. The yield of maize grain production under study was extremely high – 44-80%. The economic efficiency of maize cultivation technologies, depending on the intensity of cultivation technologies in the conditions of the northern part of the Forest Steppe of Ukraine, was assessed by V.F. Kaminskyi and N.M. Asanishvili [19] and it was proved that the fertilisation system is costly, but the increase in yield covers all added costs.

Studies on the effectiveness of added fertilisation of crops with Humilin Stimul fertiliser allowed establishing that this technological solution is effective with various forms of fertilisers and Humilin Stimul feeding against the general background ($N_{22}P_{57}K_{57}$). Yu.O. Lavrynenko, O.A. Hozh, R.A. Vozhegova also indicate the high efficiency of microfertilisers with growth stimulants for growing maize under irrigation [13]. With all the fertilisers under study, the highest effect was obtained with a one-time feeding in the BBCH 15-17 microstage (A2B2; A3B6; A4B9) (Table 4). The yield increased by 0.23-1.71 t/ha, depending on the combination of fertilisers. Fertilisation of maize in the BBCH 17-19 microstage (A2B3; A3B6; A4B9) had a lower effect with earlier fertilisation. Carrying out two feedings, both in terms of productivity and economic efficiency, was inferior to the technology with one-time feeding. Production costs differed more depending on the types of fertilisers, with which Humilin Stimul fertilisation was carried out, and varied within 27.2-29.9 thous./ha against 25.3 thousand UAH/ha in the control background variant. In case of cultivation of the ES Asteroid hybrid, high efficiency was obtained upon one-time feeding with Humilin Stimul (BBCH 15-17) on the background of UAM 32: (A3B5) production costs amounted to UAH 28.9 thous./ha; conditionally net profit – UAH 24.2 thous./ha; profitability – 84%. A similar pattern was established for the ES Concord hybrid.

An important indicator for the assessment of technological measures in the cultivation of agricultural crops is energy costs, namely the comparison of the energy accumulated in the crop to the total energy spent on cultivation and harvesting [10; 18; 22].

The calculation shows that the lowest energy consumption for growing maize was in the control variant and varied from 16,919 in the ES Concord hybrid to 17,169 MJ/ha in the ES Asteroid hybrid (Fig. 1). Energy costs increased, both due to the added fertilisers applied and due to the costs of harvesting a surplus yield (Fig. 2).

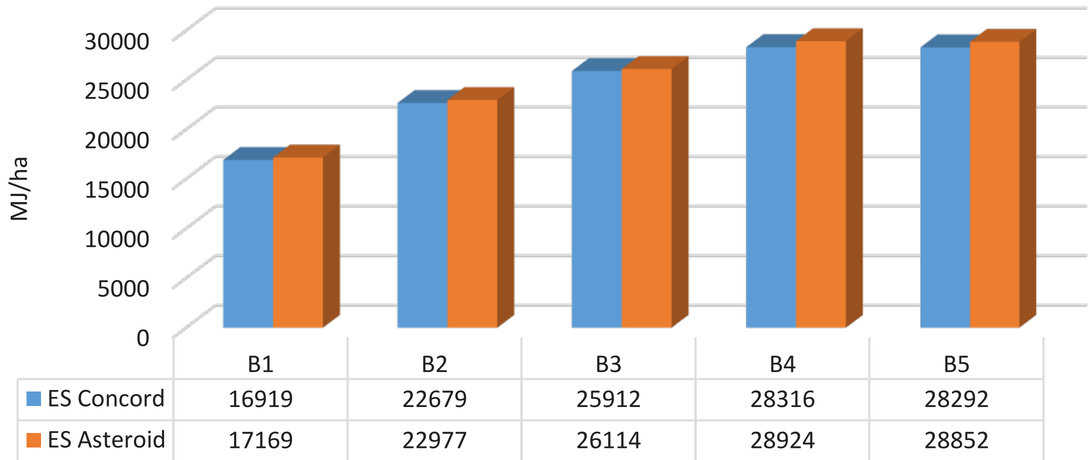


Figure 1. Energy costs for growing maize depending on the fertilisers, MJ/ha, average for 2019-2021, (Experiment 1)

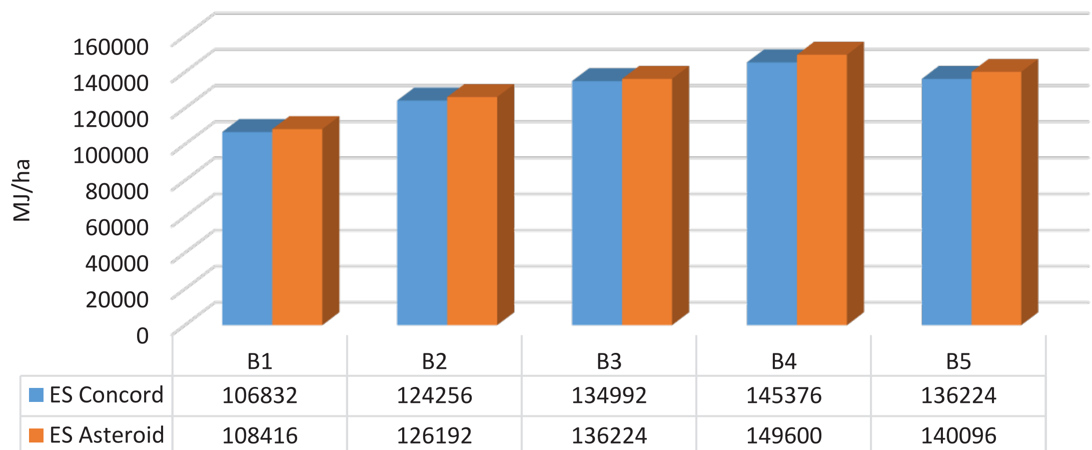


Figure 2. Gross energy yield of maize hybrids depending on the nitrogen fertilisers, MJ/ha, average for 2019-2021, (Experiment 1)

The energy efficiency coefficient has an inverse correlation with gross energy costs – it decreases with the growth of energy investments. Even an increase in productivity cannot balance energy costs and gross energy output. The energy efficiency coefficient in the control version is 6.31, with the lowest energy costs for cultivation (Fig. 3). The coefficient of energy efficiency for the application of fertilisers decreases and is 4.81-5.49, depending on fertilisers applied for the cultivation of ES Concord and ES Asteroid hybrids.

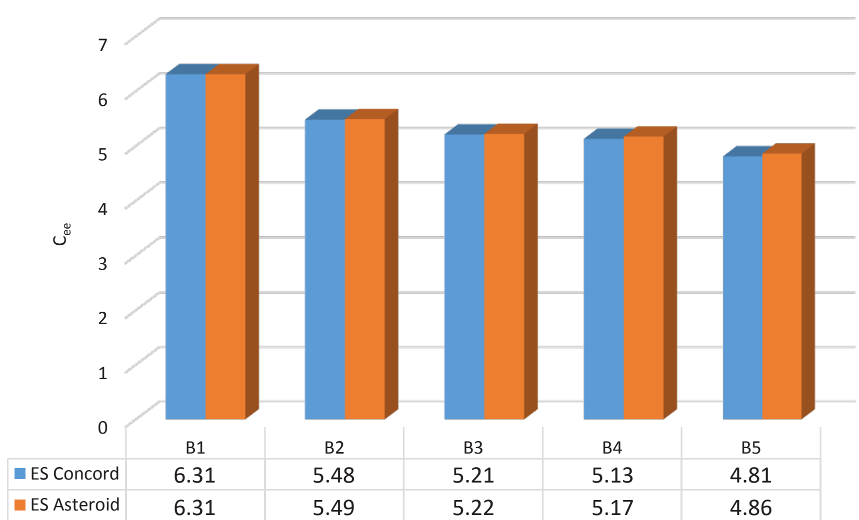
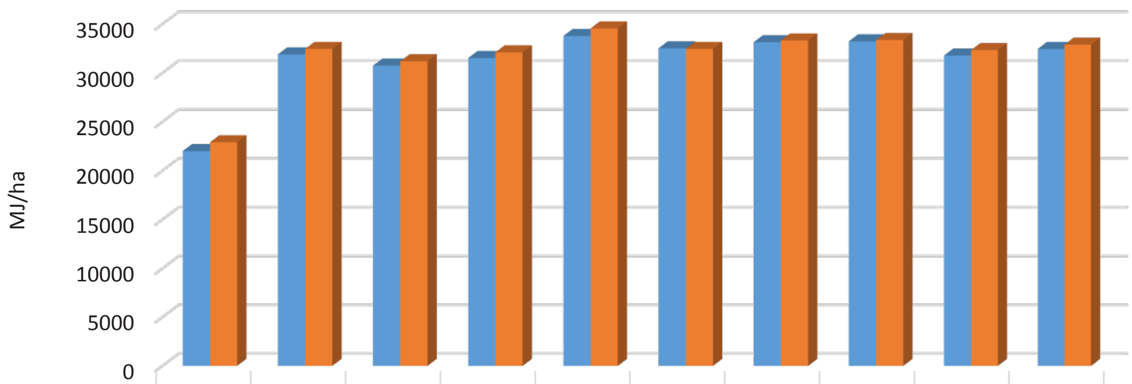


Figure 3. The coefficient of energy efficiency of maize cultivation depending on nitrogen fertilisers, average for 2019-2021 (Experiment 1)

Calculations of the economic and energy efficiency of added feeding of crops with Humilin Stimul fertiliser allowed proving the effective combinations of fertiliser and Humilin Stimul feeding. In case of the ES Asteroid hybrid cultivation, prominent efficiency was obtained from a one-time feeding with Humilin Stimul (BBCH 15-17) against the background of UAM 32: production costs amounted to UAH 28,979/ha; conditionally net profit – UAH 24,241/ha; profitability – 84% (Table 4). A similar pattern was found for the ES Concord hybrid.

When feeding maize crops with Humilin Stimul, gross energy consumption ranged from 30,752 MJ/ha to 33,361 MJ/ha (Fig. 4). The lowest technological energy costs per hectare were in the control background version – 22,000 MJ/ha and 22,900 MJ/ha, respectively, for the ES Concord and ES Asteroid hybrids.

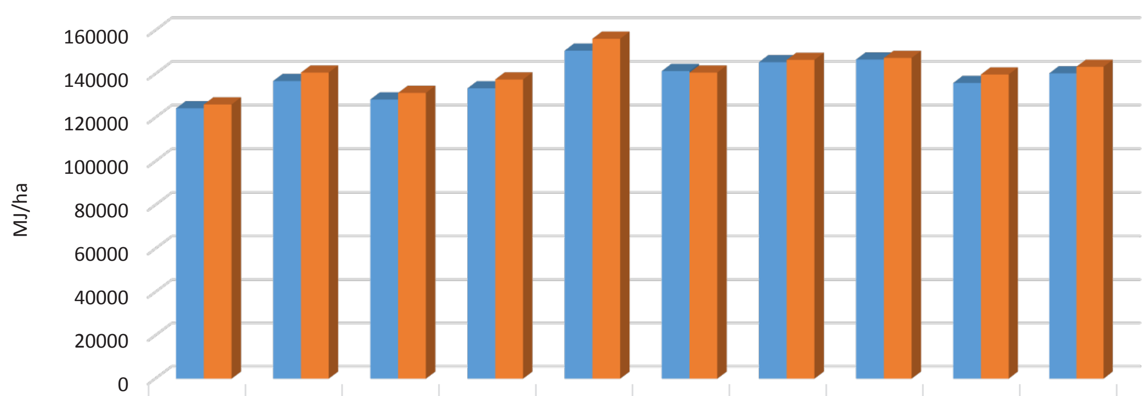


	A1B1	A2B2	A2B3	A2B4	A3B5	A3B6	A3B7	A4B8	A4B9	A4B10
ES Concord	22000	31896	30752	31523	33779	32516	33144	33231	31777	32453
ES Asteroid	22900	32456	31193	32107	34553	32456	33322	33361	32337	32893

Figure 4. Energy costs for growing maize with the combined use of nitrogen fertilisers and the Humilin Stimul preparation, average for 2019-2021, thous. MJ/ha

Higher total technological energy costs were upon one-time feeding of crops with Humilin Stimul fertiliser in the phenological phase of 5-7 leaves on the background of nitrogen fertiliser UAM 32 (N120 kg/ha a.s.) – 34,553 MJ/ha and 33,779 MJ/ha, respectively, for the hybrid ES Asteroid and ES Concord, which is associated with higher costs for harvesting an added yield.

Technologies for growing maize are characterised by elevated energy costs with a yield of 14,256-156,112 MJ/ha (Fig. 5).



	A1B1	A2B2	A2B3	A2B4	A3B5	A3B6	A3B7	A4B8	A4B9	A4B10
ES Concord	124256	136752	128304	133408	150656	141328	145376	146608	135872	140272
ES Asteroid	126016	140624	131296	137456	156112	140624	146432	147312	139744	143264

Figure 5. Gross yield energy of maize hybrids, depending on fertilisers and feeding with the Humilin Stimul preparation (Experiment 2)

Note: [1]Designation of variants in Table 2

Upon the joint application of several nitrogen fertilisers and feeding with the Humilin Stimul preparation, against the background of types of fertilisers, the energy efficiency coefficient varied from 4.17 to 4.52, in the control version it was 5.48 (Fig. 6).

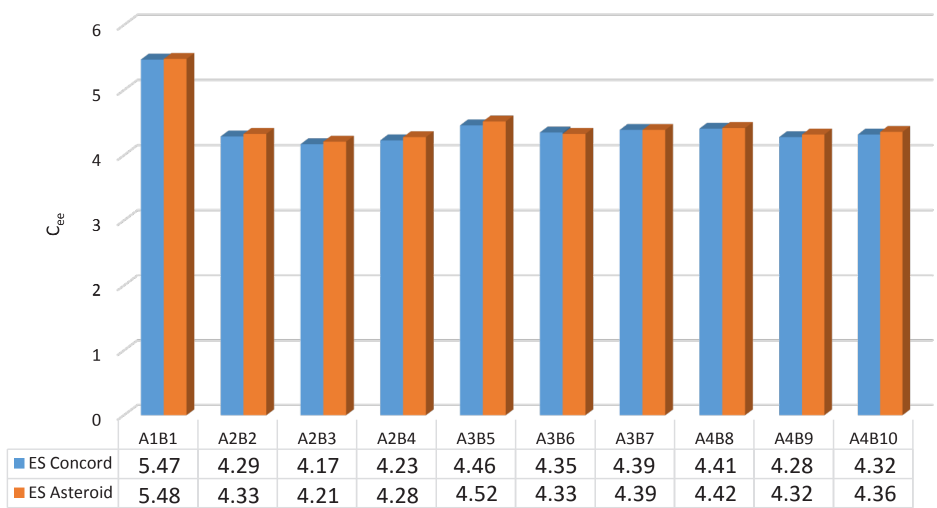


Figure 6. The energy efficiency coefficient of maize cultivation depending on the nitrogen fertilisers and feeding with the Humilin Stimul preparation, average for 2019-2021, (Experiment 2)

The decrease in the energy efficiency factor, even with increasing yield upon applying fertilisers and foliar feeding, is conditioned upon the rather elevated energy intensity of industrial chemical fertilisers.

The results of this study are original for the northern part of the Left Bank Forest Steppe of Ukraine since the effectiveness of various nitrogen-containing fertilisers for growing maize was investigated for the first time. A substantial difference in the type of fertilisers, productivity, and economic efficiency was proved.

CONCLUSIONS

Optimising the nutrition of maize hybrids using diverse types of fertilisers, application methods, and evaluating the economic and energy efficiency of growing technologies allowed proving their high economic and practical feasibility.

Maize hybrids are quite flexible to the growing conditions, respond positively to the optimisation of nutrition and form a yield that varies within 6.07 to 8.50 t/ha, and conditional net profit – UAH 15.7-24.2 thous./ha (ES Asteroid) and UAH 15.3-23.6 thous./ha (ES Concord). Application of $N_{22}P_{57}K_{57}$ in the form of DAP provides a yield increase by 0.99-1.01 t/ha, or 16.4%. Added application of nitrogen fertilisers against the background of DAP provides a yield increase from 0.57 t/ha to 1.33 t/ha, or by 7.95-18.6%. With the introduction of UAM 32, the yield increase of ES Concord amounted to 2.19 t/ha, or 36.1%; ES Asteroid – 2.44 t/ha, or 38.0%. Calculations of the economic and energy efficiency of added fertilisation with Humilin Stimul allowed proving effective combinations of fertilisers and feeding with Humilin Stimul. With the addition of Humilin Stimul, the yield increased by 0.23-1.71 t/ha, depending on the fertiliser. High efficiency was obtained with a one-time feeding of Humilin Stimul (BBCH 15-17) on the background of UAM 32 for the ES Asteroid hybrid: production costs were UAH 28,979/ha; conditionally net profit – UAH 24,241/ha; profitability – 84%. Technologies for growing maize are characterised by a high output of energy with a yield of 14,256-156,112 MJ/ha. The energy efficiency coefficient for the joint use of nitrogen fertilisers and maize fertilisation with Humilin Stimul on the background of the types of fertilisers changes from 4.17 to 4.52, in the control variant – 5.48.

The obtained results are important for the optimisation of maize nutrition and the introduction of the proposed forms of fertilisers and their combinations into production. At the same time, issues regarding the influence of different forms of fertilisers on soil biodiversity, preservation, and distribution of individual microbiological groups remain understudied. These areas of research are extremely relevant and require further investigation.

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Світлана Михайлівна Каленська[1], Олена Григорівна Каштанова[2], Віктор Петрович Каленський[1], Роман Володимирович Говенько[1], Тетяна Володимирівна Антал[1]

[1]Національний університет біоресурсів і природокористування України
03041, вул. Героїв Оборони, 15, м. Київ, Україна

[2]Університет прикладних наук Анхальт
06366, вул. Бернбурґер, 55, м. Кетен, Німеччина

Економічна та енергетична ефективність технологій вирощування гібридів кукурудзи залежно від виду та способів внесення добрив

Анотація. Актуальність вирішення проблеми зростання виробництва зерна кукурудзи є безумовною з врахуванням потреб людства, економічної та енергетичної ефективності технологій вирощування, яка суттєво залежить від виду добрив та кратності їх внесення. Метою дослідження є встановлення ефективності виробництва зерна кукурудзи за оптимізації системи удобрення. Польові дослідження проводили в фермерському господарстві «Богатирівське» Роменського району Сумської області впродовж 2019–2021 рр. на темно-сірому опідзоленому ґрунті. Математичну та статистичну обробку проведено з використанням програмного пакету SAS 9.4 та «Агростат 6». Економічну та енергетичну оцінку технологій проводили з використанням розрахункового методу. Гібриди є пластичними до умов вирощування, позитивно реагують на оптимізацію живлення – урожайність варіює від 6,07–6,16 в контролі до 8,26–8,50 т/га за застосування карбомідоаміачної селітри 32 на фоні $N_{22}P_{57}K_{57}$. За фонового внесення $N_{22}P_{57}K_{57}$ урожайність зростала на 16,4 %. Азотні добрива по фону забезпечували додаткове зростання урожайності на 7,95–18,6 %. За внесення карбомідоаміачної селітри 32 приріст врожайності склав 2,19 та 2,44 т/га або 36,1 % і 38,0 % відповідно гібриду Конкорд і Астероїд. Реакція гібридів на аміачну воду та карбамід нижча порівняно з карбомідоаміачною селітрою. Виробничі витрати на вирощування кукурудзи склали 20,3–32,3 тис. грн/га. Внесення карбомідоаміачної селітри на фоні $N_{22}P_{57}K_{57}$ забезпечувало отримання високого умовно чистого прибутку – 19,2–19,9 тис. грн/га. Рентабельність виробництва зерна кукурудзи є досить високою – 44–80 %. За підживлення Гумілін Стимул урожайність зростає на 0,23–1,71 т/га залежно від комбінації добрив. В комбінації з усіма видами добрив найвищу ефективність отримано за одноразового підживлення на ВВСН 15-17. Коефіцієнт енергетичної ефективності за внесення добрив знижується. Результати дослідження мають важливе значення для виробництва і подальших напрямів дослідження, зокрема біорізноманіття ґрунтової мікрофлори

Ключові слова: ринок зерна, урожайність, виробничі витрати, умовно чистий прибуток, рентабельність