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ECONOMIC AND ENERGY EFFICIENCY OF THE USE OF BIOLOGIZED AGROTECHNOLOGIES FOR CORN CULTIVATION

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Abstract

The study was conducted in 2017–2019 at the experimental field of the Institute of Irrigated Agriculture of NAAS (now the Institute of Climate-Smart Agriculture of the National Academy of Agrarian Sciences of Ukraine). Factor A studied different maturity groups of corn hybrids selected by the Institute of Irrigated Agriculture of the NAAS:Stepovyi, Skadovs`kyi, Inhul`s`kyi, Chonhar, Arabat. Factor B – protection system: control, water treatment; biological; chemical; integrated. The highest conditionally net profit and profitability of hybrids of all FAO groups was observed under the integrated method of plant protection. The maximum value of conditional net profit is 2.26 and 3.26 thousand euro ha^{-1} was observed in mid-late hybrids Chonhar (FAO 420) and Arabat (FAO 430) under integrated plant protection systems. The mid-late Arabat hybrid (FAO 430) showed the maximum level of profitability of 117–141%. It is most economically profitable to grow mid-late hybrids Chonhar (FAO 420) and Arabat (FAO 430) under systems of integrated plant protection.

Key words*: *corn hybrids, economic efficiency, energy efficiency, elements of technology

INTRODUCTION

Crop cultivation is of special importance for covering the demand for consumption and animal feed and, to a growing extent, also for energy [5]. The socioeconomic progress, scientific and technical advancements, and hence the economic development result in an ongoing increase in electricity and transport fuel consumption globally, which triggers an increase in the concentration of pollution and environmental degradation (water, soil, air) [22, 2, 7]. The danger that is associated with this matter is the continued increase of unemployment and famine factors, unless intensive and preventive tasks are introduced, especially in saving agro-systems transformation. At the same time, the rapid changes in the conditions of the agro-systems environment and the growing demand for new, more effective technologies require the simultaneous contribution of knowledge not only in the field of food production, but also in the field of the quality of newly created products, their marketing and maintaining the ethical principles of their acquisition, processing and distribution.

Analyzing the technology of growing corn hybrids on the irrigated lands of the South of Ukraine, we can conclude that it requires substantial expenditure of material resources, which are compensated by profit and profitability based on the results of the sale of finished products (grain). At the initial stage, it is necessary to plan the costs of resources with the help of technological maps, which should predict the costs of applying irrigation, applying mineral fertilizers, pesticides, biological preparations, soil treatments, harvesting, etc. [20].

In the conditions of climate change and the use of intensive technologies of agricultural production, disruption of crop rotations and unbalanced application of mineral fertilizers, the pressure of pests and diseases on agrocenoses has increased, as well as the level of potential clogging of the arable layer of the soil with weeds [4]. According to FAO, annual crop losses from insects, weeds and diseases are estimated at 20-40% similar to those 50 years ago [3].

Climate changes make certain corrections in the direction of deterioration of the phytosanitary condition of corn crops. Namely, weather conditions lead to an increase in the number of pathogens and pests, a shortening of their development interval and an increase in the number of generations.

In intensive agriculture with the progressive development of the agrochemical industry, the chemical method of protecting agricultural crops with the use of pesticides has dominated for a long time [8].

The list of drugs recommended for use contains a significant number of items and is constantly updated. Manufacturers offer a variety of drugs - according to active substances, terms of application, norms of use, etc. Timely application of pre-emergence (soil) and post-emergence (insurance) herbicides, as well as in combination with other elements of plant protection, can provide a significant increase in corn grain production.

A highly effective measure of protection against pathogenic microflora is the treatment of corn seeds with fungicides. In terms of efficiency, the chemical measure outperforms all others and requires consideration of phytosanitary status and environmental safety [23].

Agricultural producers, in today's conditions, to fight against plant pests and diseases of fungal and bacterial origin, are offered a significant range of chemical seed poisons, which are included in the list of permitted agrochemicals and pesticides in Ukraine. The vast majority of modern chemical poisons eliminate the problem of the spread of diseases and pests, but lead to the deterioration of the ecological condition of agrocenoses. Therefore, the biological method of protection, which is based on the use of living microorganisms and products of their metabolism, is becoming more and more widespread in agricultural technologies during the cultivation of grain crops [21, 9].

Protection of plants from diseases caused by various pathogenic microorganisms is an economically and socially important problem; losses in crop production reach 20% of the harvest in different parts of the world. The use of chemical pesticides is the main method of plant protection. However, chemical preparations have a number of serious disadvantages. Biological preparations for plant protection are now beginning to be used more intensively. The world's largest chemical companies BASF, Bayer and Syngenta show great interest in the market of biological control drugs. According to expert data, the market value of biological drugs will exceed $1 billion USD by 2025. Pesticides based on microorganisms and their products have proven their high efficiency, species specificity and environmental friendliness, which led to their introduction into pest control strategies around the world. The market of microbial biopreparations accounts for about 90% of the total volume of biopesticides, and has many opportunities for further development in agriculture [1, 10, 12, 13, 16].

Practical industrial production and use of biological preparations have been studied by numerous foreign and Ukrainian scientists [11, 12, 19, 24].

Due to the significant deterioration in recent years of the phytosanitary state of agrocenoses, primarily caused by harmful beetles such as wireworms and false wireworms, the damage caused by these pests has increased, necessitating enhanced protection measures for corn seedlings and the comprehensive control of both soil and surface pests. Withdrawal and introduction of hybrids resistant crops, particularly corn, is one of the most environmentally friendly measures in protecting plants from diseases and pests. An important issue is the evaluation assortment of modern maize hybrids for resistance against specialized pests. The most effective method of protection against corn pests is an integrated system (resistant varieties, agronomic and biological methods, chemical events) which allows incur the lowest costs until they complete avoidance when growing crops.

MATERIALS AND METHODS

The study was conducted in 2017–2019 at the experimental field of the Institute of Irrigated Agriculture of NAAS (now the Institute of Climate-Smart Agriculture of the National Academy of Agrarian Sciences of Ukraine). Factor A studied different maturity groups of corn hybrids selected by the Institute of Irrigated Agriculture ofthe NAAS: Stepovyi, Skadovs`kyi, Inhul`s`kyi, Chonhar, Arabat. Factor B – protection system: control, water treatment; biological; chemical; integrated.

The cultivation technology of corn was generally accepted for irrigated conditions and met the requirements of corn production technologies for agroecological conditions of the Steppe zone of Ukraine [18].

During the growing season, phenological observations and biometric records were performed according to appropriate methods. After harvesting a structural analysis of the cobs was performed in the laboratory of the Institute. The experiments were performed under irrigation. The main criterion for planning the irrigation regime was the level of preirrigation soil moisture (LPSM). The biologically optimal regime of corn irrigation is the regime in which at all the stages of the plant organogenesis LPSM is maintained at the level of 80% FC. The methodology of the study is generally accepted for field experiments in the conditions of irrigation and plant breeding studies with corn plant [17].

Insure®Perform – the first two-component broad-spectrum cereal seed fungicide containing strobilurin with effective disease control and a pronounced physiological effect AgCelence®. Group of Plant Protection Means (PPM) – Poisoners. Manufacturer BASF. Active substance: Pyraclostrobin, 40 g/l, Triticonazole, 80 g/l. Preparative form – liquid concentrate for seed treatment (so-called). Chemical group: strobilurins, triazoles. Toxicity class (WHO Classification) – III.

Insecticide Kanonir Duo is a contact systemic drug that protects cultivated plants from many types of insect pests. Group of PPM – insecticide. Active substance: Imidacloprid, 300 g/l, Lambda-cyhalothrin, 100 g/l. Preparative form is a concentrated suspension. Chemical group: neonicotinoids and pyrethroids. Toxicity class (WHO classification) – II.

Harness Herbicide (acetochlor, 2.0 l/ha) – selective pre-emergence soil herbicide for use on corn crops, a means of combating annual cereal weeds. Group of PPM – herbicide. Active substance: acetochlor 900 g/l. Chemical group: chloroacetanilides. The preparation form is a concentrated emulsion. Toxicity class (WHO Classification) – III.

Milagro (nicosulfuron, 1.0 l/ha) is the most dangerous graminicide for corn.Group of PPM – herbicide. Active substance content: 40 g/l Nicosulfuron. Chemical group: Sulfonylureas. Preparative form: Suspension concentrate. Toxicity class (WHO Classification) – III.

Biological insecticide-fungicide Guapsin, 150 ml (Haupsin) – a biological insecticidal and fungicidal preparation for the protection of plants from fungal diseases and pests. Composition: aqueous suspension of strains of the bacteria *Pseudomonas aureofaciens* B-111 (IBM B-7096) and *Pseudomonas aureofaciens* B-306 (IBM B-7097), products of their metabolism, starting doses of macronutrients (N, P, K). Protects plants as a fungicide against root and leaf diseases, and as an insecticide against insect pests; stimulates the growth of the root system and improves plant nutrition; increases the resistance of crops to frost and drought; does not cause resistance of pathogens; increases yield. Processing times: I phase – seed processing, II phase – tillering, III phase – flag leaf stage.

RESULTS AND DISCUSSIONS

During the studied years, an assessment of economic indicators was carried out in order to assess the economic efficiency of the studied elements of technology as widely and accurately as possible. The cost of gross production and other economic indicators of the cultivation of corn hybrids are taken at the prices that have actually developed in Ukraine (https://ukrse.com.ua/).

In order to establish the economic efficiency of the use of different FAO groups of corn hybrids, an analysis of the economic efficiency of corn grain cultivation was carried out depending on the influence of the studied factors. At the same time, generally accepted standards of production, current prices for various types of work, etc. were chosen. They were accepted according to established norms, regulations, and standards recommended for grain production in Ukraine.

To calculate the cost of gross production from 1 ha of corn sown area, the main type of production was taken as corn grain. The economic evaluation of the results of our research shows that the fluctuation of the indicators of the cost of gross production during the cultivation of corn fluctuates in directions related to the yield of the crop (Table 1).

Table 1. Indicators of the economic efficiency of growing corn hybrids depending on plant protection systems, (average for 2017–2019)

Hybrids (factor A)	Plant protection (factor B)	Economic indicators				
		Gross output value, thous. euro ha^{-1}	Spending on basic products, thous. euro ha^{-1}	Cost, thous. euro t^{-1}	Net operating profit, thous. euro ha^{-1}	The level of profitability, %
Stepovyi (FAO 180)	Control, water treatment	2.49	1.90	0.33	0.59	31
	Biological	2.86	2.01	0.30	0.85	42
	Chemical	2.80	2.05	0.32	0.75	36
	Integrated	3.06	2.10	0.29	0.97	46
Skadovs`kyi (FAO 290)	Control, water treatment	2.82	1.93	0.29	0.90	46
	Biological	3.07	2.02	0.28	1.04	51
	Chemical	3.24	2.08	0.27	1.16	55
	Integrated	3.45	2.13	0.26	1.32	62
Inhul`s`kyi (FAO 350)	Control, water treatment	3.72	2.00	0.23	1.72	85
	Biological	3.84	2.09	0.24	1.75	83
	Chemical	4.15	2.16	0.22	1.99	92
	Integrated	4.21	2.19	0.24	2.02	92
Chonhar (FAO 420)	Control, water treatment	4.00	2.02	0.22	1.98	97
	Biological	4.15	2.11	0.23	2.04	96
	Chemical	4.20	2.16	0.22	2.04	94
	Integrated	4.46	2.21	0.21	2.25	101
Arabat (FAO 430)	Control, water treatment	4.16	2.04	0.21	2.12	104
	Biological	4.70	2.16	0.19	2.54	117
	Chemical	5.11	2.24	0.18	2.87	128
	Integrated	5.56	2.30	0.17	3.26	141

Source: Own study. The gross value of the product was calculated using the prices on FOB Ukraine dated for July, 02, 2020.

The cost of gross production was the lowest, at the level of 2.49 thous. euro ha^{-1} for cultivation of Stepovyi hybrid (FAO 180). In addition, the maximum (5.56 thous. euro ha^{-1}) of this indicator was formed in the variant with Arabat hybrid (FAO 430), which is 2.3 times more than the above-mentioned variant. In Chonhar hybrid (FAO 420), the cost of gross production exceeded 4.0 thous. euro ha^{-1} for compliance with chemical and integrated plant protection.

The production costs spending on basic products for growing corn grain changed to a lesser extent in different variants of hybrid composition and plant protection and increased in the direction from early-ripening hybrids to late-ripening ones, as well as from the control variant to biological, chemical and integrated, which can be explained by the increase in the costs of harvesting an additional crop, and also for the purchase and application of plant protection products. The minimum is 1.90 thousand. euro ha^{-1} this indicator was under control in the variant with the Stepovyi hybrid (FAO 180), and the maximum (2.30 thous. euro ha^{-1}) under integrated protection when growing the Arabat hybrid (FAO 430), exceeding the worst result by 21.4%.

A noticeable decrease in the cost of 1 ton of corn grain to 0.17–0.19 thous. euro was noted in variants with plant protection in the hybrid Arabat (FAO 430). The highest value of this indicator is up to 0.30–0.32 thousand. euro t^{-1} appeared in the variant with the Stepovyi hybrid (FAO 180) in experimental plots without plant protection, as well as with biological and chemical plant protection. In other studied hybrids Skadovs`kyi (FAO 290), Inhul`s`kyi (FAO 350), Chonhar (FAO 420), this indicator occupied an intermediate value and ranged from 2.11 to 2.94 thous. euro t^{-1}.

In terms of conditional net profit, the advantage of growing Arabat hybrid (FAO 430) was shown. At the same time, the growth of this indicator to 2.54 was recorded; 2.87; 3.26 thousand. euro ha^{-1}. Therefore, there was a decrease in net income compared to the worst result in the field experiment (the control variant in the hybrid Stepovyi (FAO 180) – 0.59 thous. euro ha^{-1} by 4.3, 4.9, 5.5 times, respectively.

The level of profitability exceeded 100% for the cultivation of the hybrid Chonhar (FAO 420) in areas with integrated plant protection, as well as in all variants of factor B in the hybrid Arabat (FAO 430). Its minimum level in the range of 31.1 - 36.7% appeared in the Stepovyi hybrid (FAO 180) in the control variant, as well as under chemical plant protection.

The purpose of energy analysis in agricultural production is to optimize energy costs based on the study of energy flows at the "input" and "output" of the crop cultivation system. The total energy spent on the creation of plant products should not exceed the energy of the obtained crop accumulated in the process of photosynthesis [6]. Bioenergy assessment is particularly dependent on the intensification of agricultural production, as this is followed by an increase in the energy intensity of crop cultivation, which requires detailed calculations of the energy consumption of all technological operations. This method makes it possible to most accurately study and unambiguously express both the direct energy costs for technological processes and operations, as well as the energy invested in the means of production, as well as the obtained products through energy equivalence. This, in turn, will make it possible to identify and implement energy-saving technologies and increase the energy efficiency of crop cultivation [14].

It is customary to estimate the energy input by the size of the biological harvest formed by the culture, which includes not only the amount of the main product, but also stem, leaf and root mass, which is very difficult to estimate energetically. Therefore, scientists believe that this problem should be divided into two parts - the evaluation of the efficiency of production and the efficiency of the functioning of the agroecosystem [15]. The amount of energy input and expenditure significantly depended on the amount of crop grain yield and the technological methods of growing, which were put to study. Depending on one or another combination of experimental options, the increase in energy varied.

As a result of the dry conditions of 2019, in the field with corn hybrids, there was a slight decrease in energy input with the harvest. There was an increasing trend of this indicator in the direction from early-ripening to late-ripening hybrids, as well as from control to options with chemical and integrated plant protection. More than 80 GJ ha^{-1} of energy input occurred in the variant with a late-ripening hybrid and the use of chemical and integrated plant protection. Its decrease by more than 2 times occurred in the control variant of factor B in the plots of Stepovyi (FAO 180).

Energy consumption was minimal (31.5 GJ ha^{-1}) also obtained in the above-mentioned variant. Its growth by 20.3% (up to 37.9 GJ ha^{-1}) occurred in the variant with the Arabat hybrid using integrated plant protection. This can be explained by the increase in energy costs for harvesting an additional crop, as well as additional costs for plant protection, especially for integrated protection (Table 2).

Table 2. Energy efficiency of growing corn hybrids depending on different plant protection systems (average for 2017–2019)

Hybrids (factor A)	Plant protection (factor B)	Energy indicators				
		energy input, GJ ha^{-1}	energy consumption, GJ ha^{-1}	energy gain, GJ ha^{-1}	coefficient of energy efficiency	energy intensity, GJ t^{-1}
Stepovyi (FAO 180)	Control, water treatment	42.5	31.5	11.0	1.35	5.79
	Biological	50.0	33.0	17.0	1.51	5.17
	Chemical	48.9	33.1	15.8	1.48	5.30
	Integrated	53.8	34.4	19.4	1.56	5.01
Skadovs`kyi (FAO 290)	Control, water treatment	49.3	32.2	17.1	1.53	5.11
	Biological	53.8	33.4	20.4	1.61	4.86
	Chemical	57.0	34.0	23.0	1.68	4.67
	Integrated	60.8	35.2	25.7	1.73	4.52
Inhul`s`kyi (FAO 350)	Control, water treatment	65.6	33.9	31.7	1.93	4.05
	Biological	67.9	34.9	32.9	1.94	4.03
	Chemical	73.5	35.7	37.8	2.06	3.81
	Integrated	74.6	36.6	38.0	2.04	3.84
Chonhar (FAO 420)	Control, water treatment	70.8	34.5	36.4	2.05	3.81
	Biological	73.0	35.5	37.5	2.06	3.80
	Chemical	74.4	35.8	38.6	2.08	3.77
	Integrated	79.2	37.1	42.1	2.13	3.67
Arabat (FAO 430)	Control, water treatment	73.6	34.8	38.9	2.12	3.70
	Biological	79.4	36.2	43.3	2.20	3.56
	Chemical	82.5	36.7	45.8	2.25	3.48
	Integrated	87.0	37.9	49.1	2.29	3.41

Source: Own study.

The indicator of total energy growth showed high differences. Thus, in the variant with chemical and integrated protection for the cultivation of Arabat hybrid (FAO 430), it reached 45.8 – 49.1 GJ ha^{-1}. The energy gain decreased by 4.3–4.5 times in the variant (to 11.0 GJ ha^{-1}) in the control variant of the Stepovyi hybrid (FAO 180).

The coefficient of energy efficiency showed a clear trend of growth above 2.0 starting from the variant with the hybrid Inhul`s`kyi (FAO 350) under chemical plant protection. Moreover, the highest value of this energy indicator – 2.29, was for growing the late-ripening hybrid Arabat (FAO 430) with integrated plant protection. The lowest coefficient of energy efficiency (1.35) was obtained in the first position of the field experiment – hybrid Stepovyi (FAO 180) on the control variant (treatment with clean water). The difference between the maximum and minimum values of this indicator was 69.6%.

The energy content of the grown corn grain also fluctuated according to the dependencies shown by the other indicators discussed above. Its decrease to 3.41–3.48 GJ t^{-1} was manifested in variants with integrated and chemical protection on the hybrid of the late ripening Arabat group (FAO 430). This indicator significantly increased by 67.3 – 69.8% in the variant where the Stepovyi hybrid (FAO 180) was grown without the use of biological or chemical means of plant protection.

CONCLUSIONS

The highest conditionally net profit and profitability of hybrids of all FAO groups was observed under the integrated method of plant protection.

The lowest cost of production was observed in the hybrid Arabat (FAO 430) – 0.17–0.19 thous. euro t^{-1}.

The maximum value of conditional net profit is 2.26 and 3.26 thousand. euro ha^{-1} was observed in mid-late hybrids Chonhar (FAO 420) and Arabat (FAO 430) under integrated plant protection systems.

The mid-late Arabat hybrid (FAO 430) showed the maximum level of profitability of 117–141%.

It is most economically profitable to grow mid-late hybrids Chonhar (FAO 420) and Arabat (FAO 430) under systems of integrated plant protection.

Calculations of energy efficiency showed that with the introduction of such elements as the use of different methods of plant protection into the technology of corn cultivation, the increase in energy increased significantly from 11.0 in the Stepovyi hybrid (FAO 180 on the control variant to 49.1 in the Arabat hybrid (FAO 430) under the integrated method of protection.

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