Scientific Papers Series Management, Economic Engineering in Agriculture and Rural Development
Vol. 23, Issue 4, 2023
PRINT ISSN 2284-7995, E-ISSN 2285-3952

MAIZE PRODUCTION AND TRADE AND SCIENTIFIC-TECHNOLOGICAL SOLUTIONS TO MITIGATE CLIMATE CHANGE IMPACT IN UKRAINE

Petro BOIKO[1], Nataliia KOVALENKO[2*], Yevgen YURKEVYCH[3], Serhii ALBUL[3], Nataliia VALENTIUK[4]

[1]National Scientific Center «Institute of Agriculture NAAS», 2-B, Mashynobudivnykiv Street, Kyiv region, 08162, Ukraine
[2]Institute of Plant Physiology and Genetics of the NAS of Ukraine, 31/17, Vasylkivska Street, Kyiv, 03022, Ukraine, E-mail: boikonp@ukr.net
[3]Odessa State Agrarian University of the Ministry of Education and Science of Ukraine, 13, Panteleimonivska Street, Odesa, 65039, Ukraine, E-mail: yevgen21@ukr.net
[4]Institute of climate-smart agriculture of the NAAS, 24, Maiatskadoroha Street, Odesaregion, 67667, Ukraine

Corresponding author: boikonp@ukr.net

Abstract

The article examines the prospects of Ukraine on the world grain market and ways to increase the efficiency of maize cultivation using environmentally safe technologies in the conditions of the negative impact of climate change and other stress factors. The methodological approach takes into account the peculiarities of agrarian production based on the use of data of the Food and Agriculture Organization of the United Nations, United States Department of Agriculture, United Nations, Ministry of Agrarian Policy and Food of Ukraine and State Statistics Service of Ukraine. The dynamics of world production and export of maize grain, sown areas, production and yield of maize in Ukraine are demonstrated, which directly focuses attention on the competitiveness of Ukrainian maize on the world grain market. These arguments are confirmed by analytical results, which show that in 2022, among the world leaders of maize grain producers, Ukraine took fifth place, and among exporters – fourth. In order to mitigate the impact of climate change and other stress factors on the effective production and export of Ukrainian maize, adaptation measures are proposed, which consist in the application of modern technologies, which include: optimization of the structure of sown areas and scientifically based crop rotations with the effective use of competitive varieties and hybrids of agricultural crops, the introduction of organic and mineral fertilizers and plant protection products, the use of soil protective tillage, sideration and mulching, irrigation systems, and also the productive use of plant residues with the application of modern biodestructors. Their comprehensive implementation will contribute to the development of maize yield, grain quality, preservation of biodiversity and the solution of the grain-food problem in the world.

Key words**:** *maize, production, trade, climate change, scientific-technological solutions to sustain yield, Ukraine*

INTRODUCTION

Nowadays, the application of environmentally safe technologies based on biologization elements, which ensure the reduction of negative impact on the environment and the preservation of natural resources, and also satisfy the consumers of the world market with high-quality agricultural products, is gaining importance in the world [19; 23]. Such technologies during the cultivation of grain crops contribute to the regeneration of quality components of the environment due to self-recovery processes, and also provide a solution to the grain-food problem, especially in connection with climate changes [18; 20; 21; 24].

To reduce the negative impact of climatic changes, Ukrainian and foreign scientists have proposed environmentally safe technologies that ensure the diversification of agrarian production and reduce the riskiness of its management in different soil-climatic conditions. In particular, for adaptation to climate changes, the effective use of modern varieties and hybrids of agricultural crops with high genetic potential for productivity and quality, stable resistance to diseases, pests

and other adverse environmental factors has been established [4; 13; 22; 26; 33; 35]. Optimization of the structure of sown areas and crop rotation, which are one of the main elements of biologization, contributing to the accumulation, preservation and rational use of soil moisture, and also the regulation of the nutrient regime of the soil, was carried out [9; 10; 11; 19; 34; 36; 37]. In order to solve the problem of reproduction of soil fertility, attention is focused on the optimal application of organic and mineral fertilizers [14; 32; 39], the use of soil protective tillage [12; 45]. The effectiveness of using the natural mass of plant residues – straw of grain crops, tops and stems of maize and sunflower, husks of root crops, and also siderates has been established [2; 3; 17]. At the same time, further research into the effectiveness of the destruction of plant residues using biodestructors, which accelerate the recovery processes in the soil, is of great importance in the context of climate change.

The purpose of the article is to establish the long-term dynamics and ways of increasing the production and yield of maize in Ukraine based on the application of modern technologies, which including: optimization of the structure of sown areas and scientifically based crop rotations with the effective use of competitive varieties and hybrids of agricultural crops, the introduction of organic and mineral fertilizers and plant protection products, the use of soil protective tillage, sideration and mulching, irrigation systems, and also modern biodestructors, which contribute to the maximum use of the natural mass of plant residues, especially in the conditions of the negative impact of climate change and other stress factors.

MATERIALS AND METHODS

The information base includes a large array of information: scientific articles and statistical data of the Food and Agriculture Organization of the United Nations, United States Department of Agriculture, United Nations, Ministry of Agrarian Policy and Food of Ukraine and State Statistics Service of Ukraine.

Comparative analysis and the calculation-constructive method were used to identify the trends of changes in the main indicators of the study: world production and export of maize grain; production, yield and sown areas of maize in Ukraine during 1990–2022, which are graphically illustrated.

The abstract-logical method was used – for generalization and critical analysis, and also for the formation of conclusions regarding the effectiveness of the use of plant residues in maize crops with the use of biodestructors.

The directions of the development of environmentally safe technologies for the efficient production of maize grain in Ukraine under the conditions of climate change are highlighted.

RESULTS AND DISCUSSIONS

Maize position in the global grain production and export

Analyzing the structure of world grain production, it can be proven that maize is the leader among grain crops. In particular, in 2022, the largest share falls on grain production: maize – 42%, wheat – 28%, rice – 18%, barley – 6%, other grain crops – 6% [27]. After all, maize is a highly productive crop that is widely used in various branches of agriculture and industry around the world. For example, for the production of food products, as a high-energy feed for livestock and poultry farming, as a raw material for the production of biofuel and biogas, in the pharmaceutical, chemical and other industries, and also as a nutritious green fertilizer [1]. Thus, the valuable properties of maize ensure its steadily growing demand on the world market.

Another important factor in the increase in the production and export of maize grain is the stable growth of its global consumption due to the increase in the number of the planet's population, which during 1950–2022 has increased more than 3 times and amounts to 8.0 billion people, and in 2050, according to UN forecasts, it will increase to 9.7 billion people [30]. In particular, during 2011–2021, there is a trend of a 33% increase in world production of maize grain, which in 2021

amounted to 1,21 billion tonnes. During this period, the world export of maize grain increased by 71% and amounted to 0.20 billion tonnes in 2021 (Fig. 1). Therefore, this trend of increasing the world production and export of maize grain indicates the ability to satisfy the demand of mankind in the products of its processing.

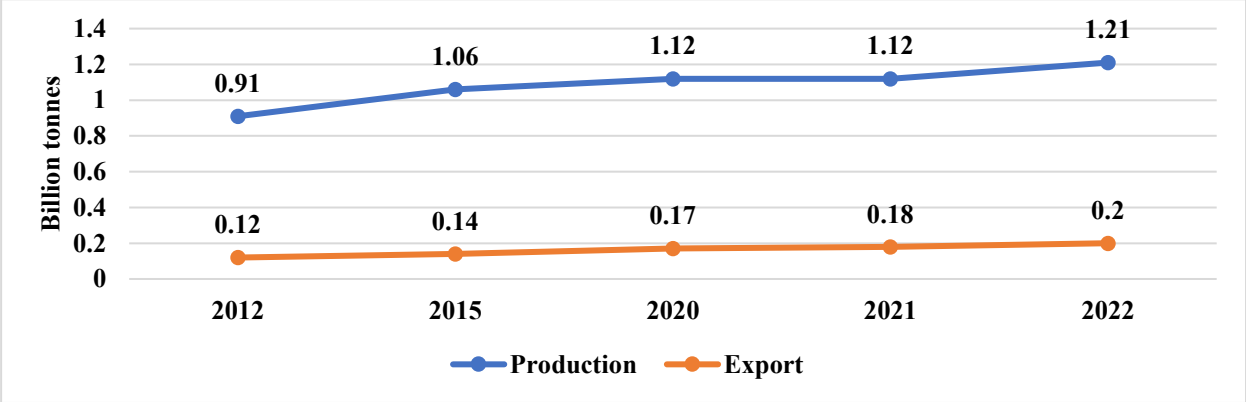

Fig. 1. Dynamics of world production and export of maize, 2012–2022
Source: Own design based on the data from [27].

However, the negative impact of climate change, which can restrain the further growth of global production of maize grain, has increased now [23; 45]. In this context, the implementation of environmentally safe technologies for the production of maize grain, the cultivation of which is widespread in 166 countries of the world, due to its high level of productivity, and also adaptability to different soil-climatic conditions, is relevant [20].

The position of Ukraine among the top maize grains producing and exporting countries

The role of Ukraine in the world market of maize grain production is becoming more significant.

If until 1992 Ukraine was not included in the top twenty at all, then in 2010 it was established in the top ten world producers of maize grain, overtaking Italy, Canada, Romania and Hungary [31].

In 2021, Ukraine entered the top five world leaders in the production of maize grain, including the USA, China, Brazil and Argentina (Fig. 2).

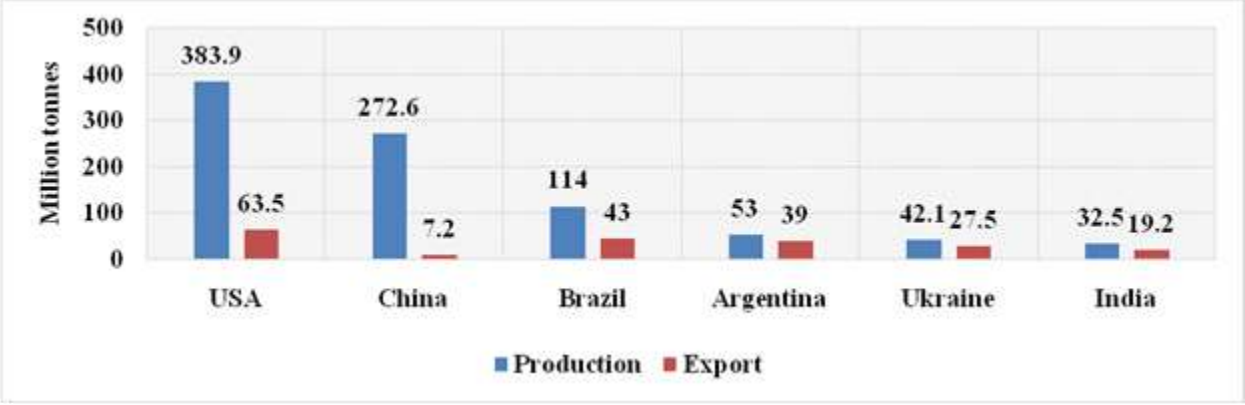

Fig. 2. Position of Ukraine among the leading countries producing and exporting maize grains, 2021
Source: Own design based on the data from [31].

After all, the total volume of maize grain production of these countries is 823.5 million tonnes or 68% of the global indicator. At the same time, Ukraine overtook maize grain production: India with 32.5 million tonnes, Mexico with 27.6 million tonnes, South Africa with 16.3 million tonnes, France with 15.4 million tonnes. In addition, in 2021

Ukraine, together with the USA, Brazil and Argentina, joined the group of the world's largest exporters of maize grain, which provided more than 85% of the export of this crop.

Ukraine's maize export and import trade partners

During 2010–2021, Ukraine expanded its activities on foreign markets by 1.5 times – from 30 to 46 countries, to which it exported maize worth more than 10 thousand dollars USA.

Every year, up to 95% of Ukrainian maize is sold on foreign markets [29]. In particular, in 2021, Ukraine exported 94.4% of maize grain to the following countries: China – 32.1%, EU – 30.4%, Egypt – 8.95%, Iran – 6.81%, Turkey – 4.38%; Israel, Great Britain – 2.39–2.72%; Libya, Korea, Tunisia, Algeria – 1.29–1.99% (Fig. 3).

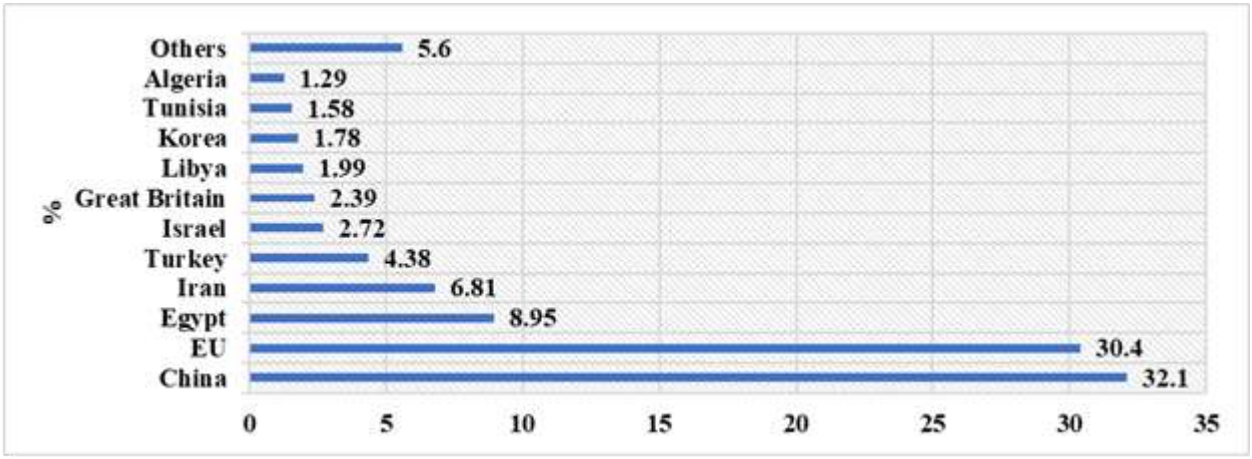

Fig. 3. Leading importing countries of Ukrainian maize, 2021
Source: Own design based on the data from [29].

China is the most promising importer and the largest maize market for Ukraine. Over the past decade, China's annual demand for maize has been constantly grown, reaching almost 300 million tonnes in 2022. Compared to other countries, in 2021 China became the main importer of Ukrainian maize – by 1.87 billion dollars USA or 32.1% [29]. In 2013, Ukraine supplied maize to China for the first time, and in 2015 it became its largest exporter (Fig. 4).

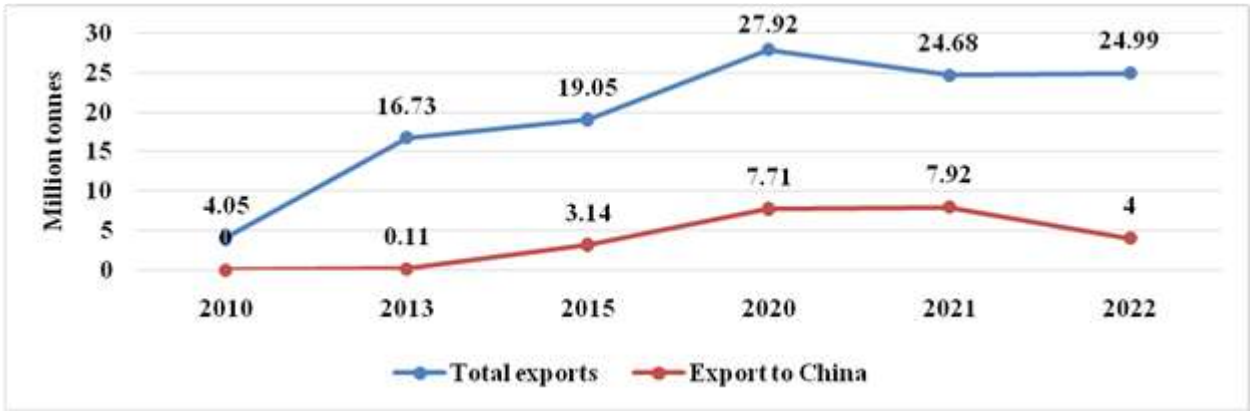

Fig. 4. Dynamics of export potential of Ukrainian maize, 2010–2022
Source: Own design based on the data from [29].

China practically did not stop buying Ukrainian maize, with the exception of February 2020, when the peak of the Covid-19 epidemic took place in the country. During 2013–2021, the total export of Ukrainian maize to China increased 70 times. In 2021, the volume of maize supplies to China became the highest in the history of

Ukrainian-Chinese agrarian trade, when China bought 28.4 million tonnes of maize on world markets, of which 7.92 million tonnes came from Ukraine. Therefore, Ukraine turned out to be the largest supplier of maize to China, providing almost 30% of imports. In 2022, maize imports into China amounted to 9.2 million tonnes, of which only 4 million tonnes were of Ukrainian origin. In 2022, China experienced a shortage of Ukrainian maize supplies, which it eliminated by using the accumulated reserves.

The growing demand of the European Union countries for Ukrainian maize is justified by their close location, which greatly facilitates logistics (Fig. 5).

Turkey, which is geographically closest to Ukraine, has become a promising market for the sale of maize grain for Ukrainian farmers. So, today Ukrainian production of maize grain is in great global demand thanks to relatively low prices and the optimal geographical location of Ukraine relative to the leading importing countries.

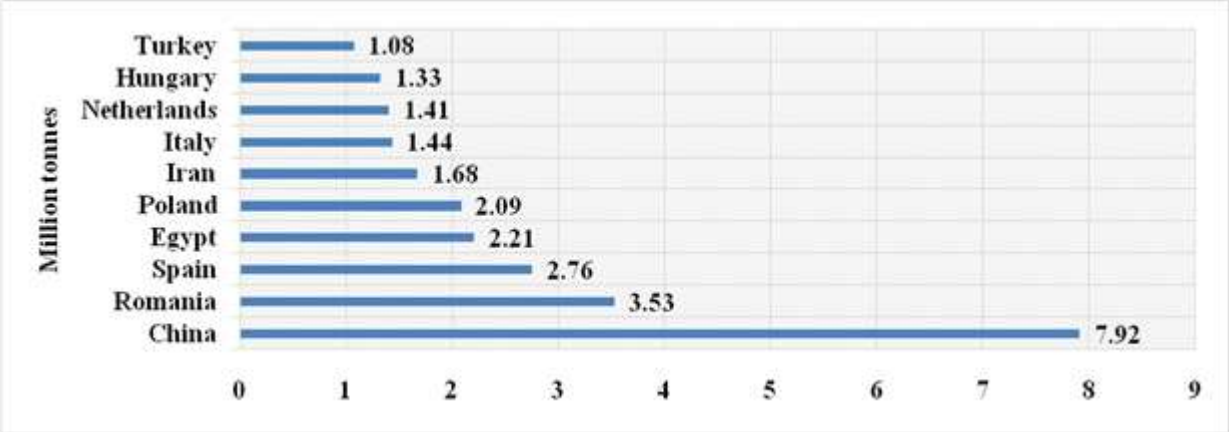

Fig. 5. Leading importing countries of Ukrainian maize, 2021
Source: Own design based on the data from [29].

Ukraine's area and population compared to other European countries

The Ukraine is the largest country in Europe by area (Fig. 6). Its land fund is 60.3 million hectares, which occupies 6% of the territory of Europe and 0.5% of the globe [25]. Ukraine guarantees efficient agrarian production, because most of its territory is occupied by humus-rich chernozem soils [5].

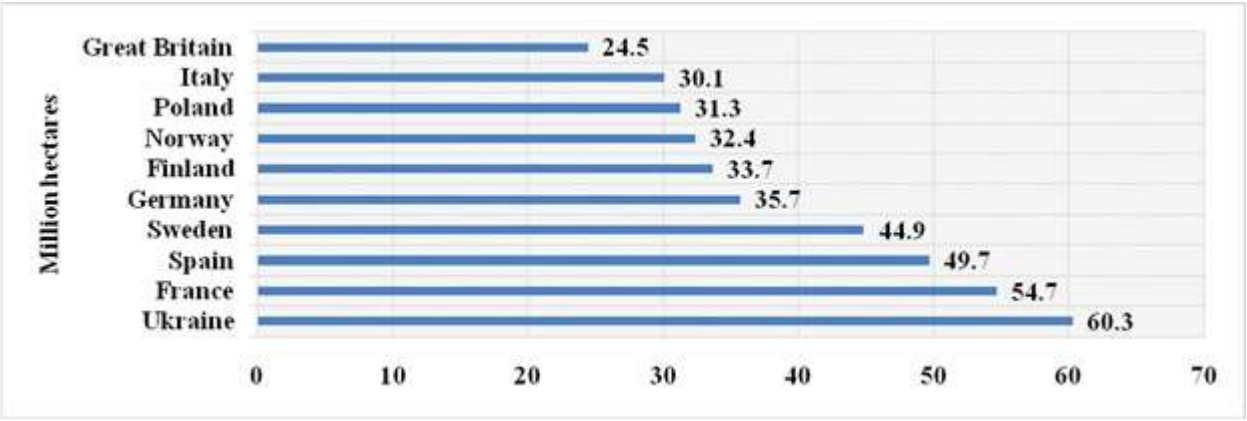

Fig 6. European countries with the largest areas of territory, 2021
Source: Own design based on the data from [25].

They provide Ukraine with a leading place in the production of wheat, barley, sunflower, maize and rapeseed. Its fertile lands can feed 600 million people [6], which is 150 million more than the population of the EU [40].

Cultivated area with maize, production and yield in Ukraine

We will analyze the dynamics of sown areas, yield and production of maize grain in Ukraine during 1990–2021. During this period, the sown areas of grain, technical and fodder crops were characterized by instability and a significant change. In particular, due to an increase of more than 4.5 times in the area of grain maize, there was an 8.9% growth in the sown areas of grain crops. Due to an increase in the areas of sunflower and rapeseed, there was by 2.5 times growth in the sown areas of technical crops (Fig. 7). At the same time, the decrease in areas of perennial and annual grasses, maize for silage and green fodder led to a reduction in the sown areas of fodder crops by 8 times [29]. Thus, during 1990–2021, the structure of grain, technical and fodder crops sown areas underwent significant changes, which caused a violation of the use of better predecessors and periods of crop return to the previous place of cultivation in crop rotations. Such an unjustified transformation led to a reduction in soil moisture reserves, a decrease in its fertility, the spread of weeds, diseases and pests, which caused a decrease in the yield of agricultural crops [45].

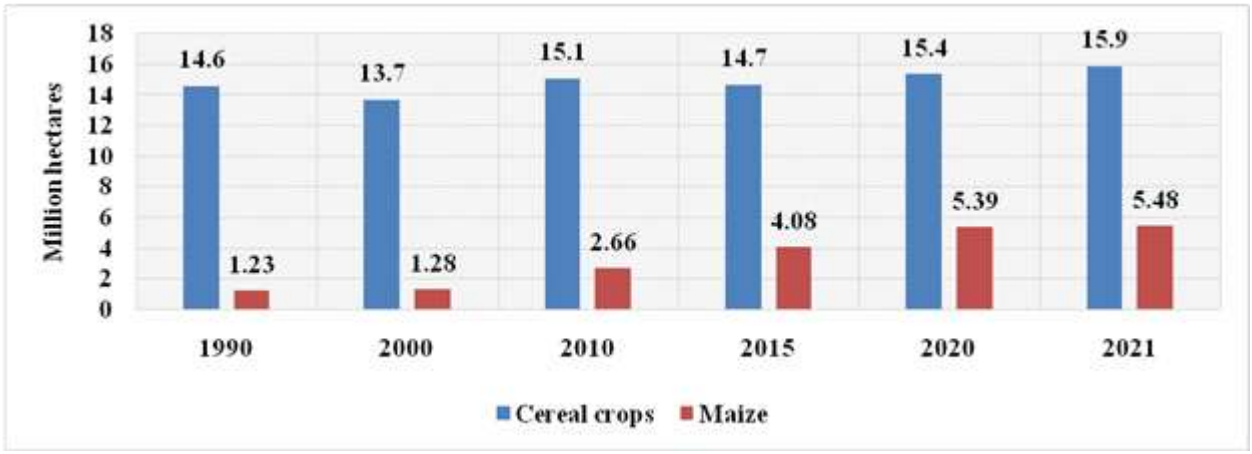

Fig. 7. Dynamics of cultivated areas of cereal crops and maize in Ukraine, 1990–2021
Source: Own design based on the data from [29].

During 1990–2021, Ukrainian agrarians developed and implemented innovative cultivation technologies that increased the national production of grain crops by 69% [29]. During this period, the production of grain maize increased almost 9 times, but due to the expansion of sown areas (Fig. 8).

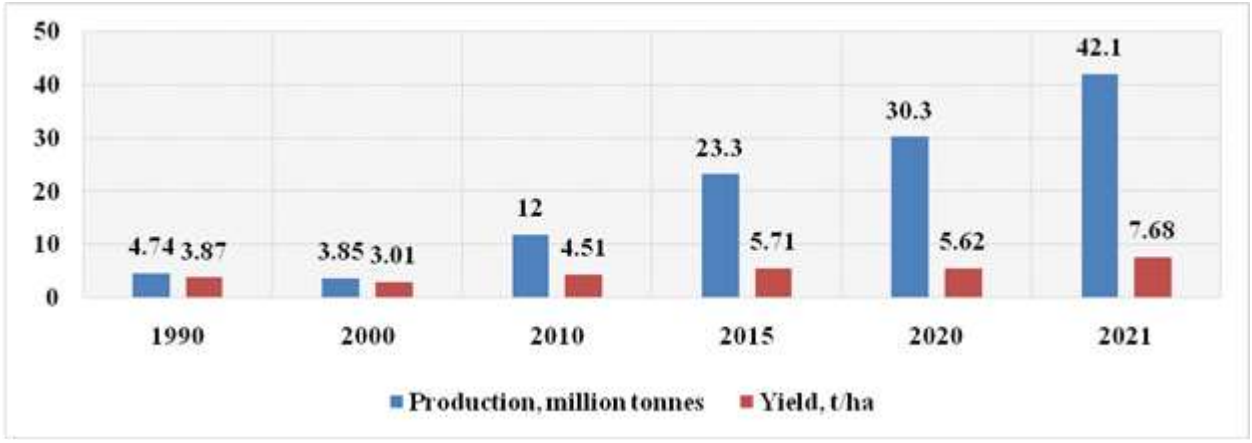

Fig. 8. Dynamics of production and yield of maize in Ukraine, 1990–2021
Source: Own design based on the data from [29].

Due to the violation of crop rotations, soil degradation increased, which negatively affected the yield of grain maize, which increased only 2 times and in 2021 was 7.68 t/ha, which is much lower than the potentially possible level in the EU countries – 10 t/ha [27].

In 2022, the sown area of grain crops decreased to 11.7 million hectares, maize – to 4.63 million hectares, which negatively affected production. Only 53.1 million tonnes of grain crops were collected with a yield of 4.54 t/ha, including maize grain – 25.6 million tonnes with a yield of 5.53 t/ha [28].

These are the lowest indicators in the last ten years, which were negatively affected a decrease in the sown and harvested areas.

Challenges in agriculture due to climate change and scientific-technological solution to mitigate their impact

There are also negative factors: climatic conditions – rainy summer and autumn, destabilization of fertilizers for plant protection products, and also a shortage of elevators, due to which part of the maize crop was left to winter in the field.

During 1880–2020, the average annual air temperature on the planet increased by 1.1°C. At the same time, in the regional aspect, such an increase occurs unevenly. For example, during this period, the growth rate of the average annual air temperature in Europe is 1.7°C, in Ukraine – 2.2°C, including during 1990–2020 – 1.2°C [16]. Thus, warming in Ukraine occurs at a faster pace, although the average annual precipitation remains practically unchanged: in the Steppe – 350–450 mm, in the Forest-Steppe – 450–550 mm, in the Polissia – 550–650 mm [45]. At the same time, an increase in air temperature increases the evaporation of moisture and causes its redistribution. As a result, excessive moisture evaporates in some regions and droughts intensify. In other regions, moisture condenses and causes frequent downpours and storms that cause flooding risks. For example, during 1990–2020, Ukraine experienced an uneven distribution of precipitation and rainfall intensity, which are torrential in nature and cause inefficient accumulation of moisture in the soil [7]. In particular, when the monthly rate of precipitation falls in a few hours, and in another period there is no rain at all, which increases the intensity and duration of droughts. In addition, an increase in the average winter air temperature by 1–2°C causes a change in the systematicity of seasonal phenomena – snowfall, spring floods, and the beginning of flowering [16].

Due to climate change, long-term and extreme heat waves are spreading around the world. For example, heat records were recorded in the summer of 2019: in Germany – 41.7°C, in Belgium – 41.8°C, in France – 42.6°C. In 2021, a heat wave with a record air temperature of 49.0°C was recorded in Canada. In the summer of 2022, the heat record exceeded 40.0–43.0°C in Great Britain and France, and the highest air temperature was recorded in Portugal, which was 47.0°C [7]. Therefore, heat waves caused by climate change represent the greatest climatic danger and lead to temperature extremes in many countries of the world. It can be concluded that Ukraine belongs to the number of regions of the planet where climatic changes are becoming quite noticeable, especially in the direction of increasing aridity, which reduces the productive potential of agricultural crops.

In 2023, high prices and a shortage of fuel, mineral fertilizers and plant protection products will lead to a decrease in the yield and productions of grain crops, in particular maize. To mitigate the impact of today's global challenges and threats on maize yield and production, a wide range of adaptation measures is proposed:

(a) the use of modern varieties and hybrids of agricultural crops with high genetic potential for productivity and quality, stable resistance to weeds, diseases, pests and other negative environmental factors;

(b) the optimization of the structure of sown areas and scientifically based crop rotations with the cultivation of traditional and rare crops;

(c) the application of effective predecessors of agricultural crops and periods of their return to the previous place of cultivation in crop rotations;

(d) the introduction of organic and mineral fertilizers, which ensure regulation of the nutrient regime of the soil;
(e) the introduction of biological plant protection products against weeds, diseases and pests;
(f) the implementation of soil protective tillage, which contributes to the accumulation, preservation and rational use of soil moisture;
(g) the sideration and mulching;
(h) the irrigation systems;
(i) the productive use of the natural mass of plant residues – straw of grain crops, tops of maize and sunflower, husks of root crops;
(j) the use of modern biodestructors for transforming plant residues into organic matter destined to nourish the soil and improve its fertility.

In this respect, environmentally safe technologies for growing maize include the application of modern biodestructors to accelerate recovery processes in the soil based on the decomposition of plant residues [8; 15; 41]. Modern biodestructors include preparations of Ukrainian production: Cellulad of mushroom origin – developed by specialists of «Enzim-Agro» Trading House LLC [3], Ekostern of bacterial origin – developed by specialists of «BTU-Center» company [38]. These biodestructors simultaneously suppress pathogenic microflora and improve the soil, enriching plant remains with useful and viable microorganisms, fungi and bacteria at low and high temperatures [42; 43; 44]. Thanks to their complex application with organic and mineral fertilizers and siderates in scientifically based crop rotations, the level of soil fertility and productivity of agricultural crops increases by 10–30% [3]. In arid conditions, the degree of destruction of plant residues when using irrigation increases by 2.2–2.6 times [3].

CONCLUSIONS

It can be concluded that thanks to the increase in the number of the planet's population and the valuable properties of maize grain, a stable growth in its global consumption has been ensured. On the basis of a comparative analysis, it was established that during 2011–2021, the world production of maize grain increased by 33%, export – by 71%. The calculations showed that in 2021, Ukraine entered the top five world leaders of producers and the top four world leaders of exporters of maize grain. It has been proven that due to relatively low prices and optimal geographical location, China and the countries of the European Union: Romania, Spain, Poland, Italy, Netherlands and Hungary became the leading importers of Ukrainian maize.

The comparative analysis showed that during 1990–2021, the production of grain crops in Ukraine increased by 69% due to an increase in the production of maize grain by almost 9 times – from 4.74 to 42.1 million tonnes due to a 4.5-fold increase in its sown area – from 1.23 to 5.48 million hectares. Due to high competition in the foreign market, the sown areas of technical crops increased by 2.5 times thanks to the expansion of sunflower and rapeseed. At the same time, the sown areas of fodder crops decreased by almost 8 times due to the rapid decrease in the sowing of perennial and annual grasses, maize for silage and green fodder.

Based on the calculations, it was found that the violation of scientific technologies, along with the negative impact of climate change and other stress factors, caused a decrease in the yield of grain maize. These arguments are supported by analytical results, which show that during 1990–2021, the yield of maize grain in Ukraine increased only 2 times – from 3.87 to 7.68 t/ha and is significantly lower than the potentially possible level.

The comparative analysis showed that in 2022, it was recorded a sharp decrease in the yield of maize grain reaching the lowest level in the last ten years – 5.53 t/ha, which, along with a reduction in the sown area by 15%, caused a decrease in the production of maize grain by 1.7 times.

A number of adaptation measures are proposed to overcome the negative impact of climate change and other stress factors, which consist in the use of environmentally safe technologies for the cultivation high-yielding

maize and include the application of modern biodestructors to accelerate recovery processes in the soil based on the decomposition of plant residues. The effectiveness of the use of modern biodestructors increases along with the introduction of scientifically based crop rotations, the introduction of organic and mineral fertilizers, plant protection products, the application of soil protective tillage with sideration and mulching, irrigation systems, which will ensure the competitive production of maize grain in different soil-climatic conditions of Ukraine and the world, especially in connection with climate changes.

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