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PLANT HEALTH PROGRESS FOR BOOSTING FOOD SECURITY

Starting from increasing the impact of phytosanitary agents and deepening the ecological problems caused by their combat, it becomes rational to change the paradigm of the protection of plants with their health. The purpose of the paper is to highlight and establish the role of the main factors that are the basis of plant health and how they determine the phytosanitary status of agroecosystems and the degree of food security. Research methods and methodology are oriented to the identification and determination of the biological peculiarities of agents, as well as the biological, ecological and economic analysis of protection means of agricultural crops. As effective measures in promoting plant health, it is proposed to apply the link between soil, plant and human health, the role and place of GMOs in solving phytosanitary problems, the perspectives of genome editing, the expansion of the implementation of regenerative agriculture. In order to overcome this problem, the paper contains information on the possibilities of application of synergic phenomena in plant protection, the interaction between which provides a significant increase in performance indicators and stability of the system state. The article describes the role and place of several factors: link between soil, plant and human health, the role and place of GMOs in addressing phytosanitary issues, prospects for genome editing, activities to extend the implementation of regenerative agriculture, synergic phenomena as direction to increase the effectiveness of plant protection means and other phenomena that determine food security and food safety, the achievements of the institute in the direction of the development and implementation of biological means of plant protection, especially biological preparations.

biopesticides; ecological agriculture; pests; plant health; synergic phenomenon; sustainable development

Introduction. The evolution of phenomena related to the increasing impact of climate change on phytosanitary status and the need to highlight and strengthen adaptation capacities is one of the fundamental directions, which at global level requires a special and urgent approach. Awareness and mitigation of the effects of this impact can register consistent results only at the active collaboration of all national bodies in the field and international organizations working in this particularly important field. The aggravation of the problems related to the increase of losses caused by harmful organisms on the background of climate change lies in the modification of the epidemiological peculiarities of phytosanitary agents and the increase in the prevalence of pests by manifesting various difficulties in carrying out technological procedures for producing agricultural crops [1]. As a consequence of massive pollution, as a result of pesticide application and the danger of reducing biological diversity and aggravating ecological problems, the United Nations through the Food and Agriculture Commission (FAO) declared 2020 International Year of Plant Health [2].

Starting from the global role of plants and the need to develop ecologically friendly means of combating harmful organisms, a scientific analysis of phytosanitary risk factors was undertaken to assess the impact of climate change on plant health and adapt them in order to reduce production losses and maintain the ecological status of agroecosystems by applying natural mechanisms. In this regard, key information on the role of plants in nature is indispensable: they represent 80% of the food we eat and produce 98% of the oxygen we breathe, the annual value of agricultural trade reached 1.7 trillion.$, by 2050 agricultural production should increase by 60% to provide food for the growing population of the Earth, harmful organisms cause up to 40% crop losses and reduce annual trade in agricultural products worth $220 billion, climate change threatens not only to reduce crop biodiversity, decrease crop yields but also their nutritional value, rising global temperature causes increased damage to crops, beneficial insects, play a vital role in plant health, The biological diversity of which has reduced by 80% over the past 25—30 years, a million locusts per day damage about a ton of food, and large swarms consume up to 100.000 t/day [3].

The global role of plants and highlighting the needs to ensure their health elucidates the link between soil, plant, animal health, which for now remains poorly researched and explored, because they have been focused on investigating problems, but not on promoting the health of these global elements. The soil, through the accumulation of pathogens and pests, toxic, radioactive or chemical effects of contamination, either natural or anthropogenic, contributes to the occurrence of negative phenomena on biota, and on the other hand, through deficiencies or excesses of nutrients causes direct effects on plants and animal health.

By solving phytosanitary and environmental problems, only by addressing and applying natural mechanisms, applied in organic and regenerative farming systems, it becomes possible to develop intensive agricultural systems, which, thanks to the effects of management on soil and plant health, are the basis for understanding possible links between soil, plant and human health and are the key to improving the quality and safety of food grown in all agricultural systems.

Climate change and human activities have affected ecosystems, reduced biodiversity and creating new niches for harmful organisms to grow. At the same time, international travel and trade have tripled over the past decade, accelerating the spread of phytosanitary agents on Earth and causing damage to crops and the environment. Plant health is much more cost-effective than emergency intervention when plants are at the stages of manifesting symptoms and economic losses. Pests and disease pathogens are often impossible to eradicate once they have set in, and managing them is expensive and time-consuming. Prevention activities are inevitable to reduce the devastating impact of pests and disease pathogens on agriculture, livelihoods and food security.

In order to ensure the biological efficacy of ecologically friendly means of reducing the impact of harmful organisms, we managed to demonstrate the role and efficiency of synergism when comparing the biological efficacy of biological preparations, components of the agricultural system, as well as their concomitant action. Convincing results were recorded when using principles and techniques in researching the efficiency of the action of biological preparations proposed for the elaboration of the concept of synergism aimed at increasing the effectiveness of the elements proposed for conventional and organic farming systems.

Material and methods. For research, phytophagous insects and various strains of viruses, bacteria, fungi and other useful organisms were used. Their testing was performed in 4 and randomized repetitions, respectively, in accordance with the general requirements of such experiences. The accumulation of biological mass requires the presence of biological agents, and the determination of its quality and preparative forms was carried out by applying means of visualization and determination of biological, economic and ecological effectiveness.

Research of the phases of the production process biological bags carried out in optimal conditions that contribute to the accumulation of biomass, the constitution of preparative forms, preservation and application of the required preparation.

The situation in the field of plant protection and environment was analysed by applying the methodology of systemic approaches, as a tool of complexity management and as one of the essential paradigms of the future [4].

Results and discussion

Link between soil, plant and human health

Information on the effects of farm management practices on soil and plants, human and animal health, and product quality is becoming increasingly common. They are manifested by the application of diversity of varieties, soil, tillage systems and application of different technological processes, fertilizers and sanitary means, time of harvest, duration and type of storage of the product. Soil quality or health to increase plant resistance to abiotic and biotic stress is an area of research, which maintains elements geared towards increasing resistance to harmful organisms. Efforts to penetrate into the essence of the investigated phenomena and to understand and link the effects of quality management become oriented towards the elaboration of agricultural systems that have beneficial effects both on the environment and on mental and human health [5].

The composition and elements of soil biota are a dynamic indicator of plant health and soil quality, which manifests itself through the three categories: physical, chemical and biological. The physical properties of the soil, affect the depth of penetration of the root system, water availability and aeration. Demonstrating the benefit of soil biota on plant health, starting from the high diversity of entities, is a valuable indicator of effects on plant growth and health, which requires deep approach and research [6].

The chemical properties of the soil manifest profound action on plant health through profound effects on plants and increasing its yield. The use of composts influences the number of organic substances and contributes by increasing humus and its derivatives, which influences nutrient chelation, supply and storage, as well as expanding the availability of nutrients in the soil and strengthening plant health and agronomic potential important, but possible complicating factor. The health status of plants, in particular susceptibility to harmful organisms, becomes lower with the supply of large amounts of soluble nutrients, especially nitrogen fertilizers. Thus, optimizing crop yields is an important agricultural objective and can be an indicator of plant health, and applying fertilizers in optimal quantities helps control the density of pest populations [7].

Knowledge of the role of soil microbiome, plant genotype and crop rotation, interactions in nutrient transformation are levers to achieve indices on efficiency of use, environmental stability and plant health, as well as human health in sustainable agriculture systems to distinguish potential effects in ensuring human health. It is necessary to mention the possibilities of determining the capacities of different agricultural systems and ecological management in strengthening human and animal health.

The role and place of GMOs in solving phytosanitary problems

The solution of ecological problems in agriculture can become reality with the complex use of ecologically friendly measures to control the density of populations of harmful organisms, of which biological methods of combating with the application of technologies of production and application of microbiological means are preferable. Food security and food safety are based on the application of advanced technologies, as well as approaches aimed at increasing crop productivity, which are not sufficient and sometimes only mask the adverse effects on the environment. The solutions come from biotechnological investigations with consistent potential to generate increased productivity with reduced inputs and obtaining plant entities with increased resistance to adverse conditions and challenges caused by climate change.

Over the past decades, plant genetic research has yielded consistent results to regenerate the first genetically transformed plants with foreign genes and to cultivate transgenic plants widely. Genetically modified organisms (GMOs) feature prominently in strategies to tackle global problems, including food security, as well as the transformation of plant species, which require pest control. Currently GMOs occupy large areas (189.8 million ha), and 4 crops (soybeans, corn, cotton and rapeseed) reach about 90—100% of the occupied areas, but their application is not univocal, and their risks to the environment and health are becoming more and more obvious.

The advantages of genetic engineering for phytosanitary protection purposes result from traits borrowed from other organisms, such as resistance to harmful organisms, tolerance to herbicides.

Herbicide tolerance. It is obtained by introducing a bacterial gene that codes for resistance to some herbicides by transferring the gene that codes for information on ferment biosynthesis, which inactivates the herbicide and ensures the plant's resistance to it. By transferring the 5-enolpyruvat-shikimat-3-phosphate-synthase (EPSPS) gene from Agrobacterium tumefaciens (strain C4) to soybeans, plant tolerance to the herbicide glyphosate was induced by intervention on the enzyme EPSP-synthase. As a result, the gene coding for the enzyme was modified, ensuring its activity in the presence of glyphosate, and then transferred to crop plants, inducing resistance to the herbicide.

Insect resistance was achieved by transferring to agricultural plants the *cry* gene taken from entomopathogenic bacteria (*Bacillus thuringiensis)* that codes for the expression of a toxin with insecticidal properties and does not show toxicity to humans. The inclusion of the *cry* gene (*cry1Ab, cry1Ac, cry1F* and cry9C) of the endotoxin Bacillus thuringiensis (84 pathovariants) in the genome of agricultural crops ensures the resistance of the host plant to insect pests and the reduction of the pesticide press.

Plant resistance to phytopathogenic viruses and other pathogens is obtained by introducing genes from certain phytopathogenic viruses, registering increased resistance against pathogens and their express identification. It is acquired by cloning and transfer to culture plants of genes coding for viral capsid proteins, thus obtaining resistant cultures of zucchini resistant to tobacco mosaic virus and other plants resistant to alfalfa mosaic virus and cucumber mosaic virus.

Plant resistance to fungi and bacteria is recorded by applying natural resistance to these pathogens. The effects are determined by proteins related to pathogenesis processes, called PR proteins, with enzymatic functions that cleave the cell envelopes of microscopic fungi (chitinase), as well as various compounds and antifungal and phytoalexin proteins, which ensure the resistance of crop plants against mycotic and bacterial pathogens. The development of GMOs has been the basis for many hopes related to the recording of beneficial results, especially quantitative and qualitative indicators, as well as the improvement of the state of the environment, but has caused various concerns and controversies regarding the risks related to the development of superweeds, new viruses, microorganisms resistant to antibiotics, undesirable effects on non-target organisms and humans, loss of biodiversity, disorders in the structure of ecosystems and their impact on humans and the environment.

The severity of the problems related to the negative consequences of GMOs on human health and the environment has a positive trend also due to the lack of techniques and ways to quantify the associated risks. Starting from the modest information mass on the action of GMOs over several generations, it becomes obvious that the scientific community cannot neglect the possible risks of GMOs to humans, non-target organisms and the environment [8].

The risk assessment of GMOs and their products considers two important components: environmental risk and human health. The Cartagena Protocol on Biosafety, adopted in 2000, outlines steps to be taken in risk assessment, looking for the characteristics of modified living organisms (OVMs) that could have negative impacts on biological diversity, the environment into which they are released and human health [9].

Prospects for genome editing

Biotechnological advances in modern agriculture constitute one of the most significant achievements and challenges in the coming century. Political and social controversies, as well as difficulties encountered in plant breeding and solving global environmental problems, have compromised the promised positive effects of gene and genetic engineering in obtaining and applying GMOs.

The complex nature of issues related to food security, human health and the state of the environment determines the need to apply the capabilities of modern biotechnologies to penetrate the mechanisms constituted during the evolution of the biosphere, obtaining genome editing levers. In this regard, new plant breeding techniques are applied, such as synthetic nucleases: zinc finger nuclease, TALEN nuclease, CRISPR-Cas9 system, oligonucleotide-directed mutagenesis, cisgenesis and intragenesis, RNA-mediated DNA methylation, grafting on genetically modified rootstocks, agroinfiltration, agroinoculation, which allow the induction of targeted changes in the genomes of organisms. They allow genetic information to be modified to generate new properties, remove specific regions from the genome and add transgenes at specific locations in genomes, and represent considerable advances in plant improvement and phytosanitary protection.

CRISPR (clustered regularly interspaced short palindromic repeats) technology, whose potential was first demonstrated by Jennifer Doudna and Emmanuelle Charpentier in 2012, allows modification of the genome of any biological entity and was recognized as invention of the year 2015. CRISPR is a tool to correct DNA defects and works like molecular scissors that allow unwanted areas within the genome to be selectively cut out and replaced with new DNA fragments. This technology will revolutionize the study and treatment of a huge range of diseases in humans, plants and animals, including cancers and incurable infections, as well as hereditary diseases. Current scientific advances demonstrate that CRISPR is not just a highly versatile technology, but one that is proving to be accurate, increasingly safe to use, and forward-looking. Gene editing provides efficiency and precision by reducing R&D and breeding periods and for combating rapidly evolving pests [10].

CRISPR-Cas9 as a genome editing platform has proven to be flexible for species, has great multiplexing potential, although a number of technological difficulties and intellectual property constraints remain. Because the technology leaves no signs of transgenesis, plants generated by genome editing are not considered GMOs and do not provoke the political and social discussions and challenges that still accompany agricultural biotechnologies. Thus, GM plants could be excluded from EU GMO rules.

Activities to extend the implementation of regenerative agriculture

Activities in the field of regenerative agriculture, aiming to protect and regenerate natural systems (soil, water, biodiversity) oriented to the food insurance of mankind, aim to surpass the achievements of sustainable and ecological agriculture. Even if there are various problems related to the term «regenerative», however, it is necessary to recognize that it is precisely by applying natural mechanisms, established during the multimillennial evolution of nature, that it becomes possible to apply means that can mitigate the impact of climate change. It is becoming obvious that activities aimed at reducing greenhouse gas emissions alone cannot solve climate change, because hundreds of billions of tons of carbon need to be extracted, and restoring soil is the only known way to do this [11].

Namely, regenerative agriculture, as a holistic land management practice, can harness photosynthesis in plants to close the carbon cycle and build soil health, crop resilience and regulation of pest population density, without applying GMO production and application processes. Regenerative practices focus primarily on restoring soil biota and fertility. These include the use of cover crops, rotations, compost to enhance soil fertility, protect the diversity of biological ecosystems and soil biota; and well-managed grazing practices to improve plant growth, soil fertility, diversity of useful entomofauna and soil carbon capture. In this way, regenerative agriculture imitates nature and represents how nature would cultivate, and anthropogenic actions can improve the health of soil and other elements of the biosphere, as well as maintaining biodiversity [12].

Starting from the galloping tempos of the impact caused by climate change and the reduced effect of biotechnologies oriented to obtaining and implementing GMOs with the manifestation of negative phenomena related to their use, humanity is constantly moving technological procedures to solve global environmental problems, among which it is worth mentioning: reduce greenhouse gas emissions by 55% and pesticides by 50% by 2030, reduce nutrient losses by 50% without danger of damaging soil fertility, including a 20% reduction in the use of mineral fertilizers, organic farming on 25% of agricultural land, allocate 10% of the household area at landscape level under natural vegetation.

The agroecological principles of sustainable and resilient soil management are analogous to those of natural ecosystems and include: permanent presence of living roots in the soil, permanent soil cover with plant debris, large diversity of main and successive crops in rotation at the level of each lot and landscape. This is how the close link between soil health — plant health — animal health — human health — planetary health is recorded.

Analyzing the many beneficial results associated with the use of regenerative production practices, we can mention that over the past years there has been an increase in attention to this type of agriculture. However, financial results are crucial for the discussion about the transition to regenerative agriculture, as the prospect of positive financial returns is crucial to boost agricultural profitability and maintain environmental conditions.

Synergic phenomena — direction to increase the effectiveness of plant protection means

The elucidation and application of the mechanisms of interaction between harmful and useful organisms, which constitute the basis of the dynamic balance within agroecosystems, requires their deep study and knowledge and can become reality only to the complex systemic approach through the full use of the intellectual capacities of scientists in the field of biology and agriculture. The realization of this desideratum becomes possible by using the phenomenon of synergism, which are natural sources of intensification of actions, which are exerted in the same sense, as well as the creation of a whole that is greater than the simple sum of its parts and signifies «working together» and defines the increased effect that can be obtained by the simultaneous action of several physical, biological, economic and social elements.

The synergistic interaction of the factors applied in our research (biological agents at different stages of evolution, which are the basis of ecologically harmless means of plant protection, means approved or proposed for testing, as well as various natural and technological factors, which greatly influence the total effect, manifested by phytosanitary indices, the quantitative and qualitative value of crops, which exceeds the effect of each individual element. To assess the degree of such interaction, a synergistic amplification coefficient is used, which shows how many times the biological effect increased with combined action compared to that expected with the independent addition of effects from each agent used in the combination. Particularly important is phytosanitary analysis and permanent monitoring of harmful organisms, as well as the examination of plots and plots within rotations for their rational use, which contributes to encouraging that organic farming is a sustainable agriculture of the future [13].

As a way to solve problems related to the phytosanitary status of agroecosystems is the integrated management of harmful organisms, as a system for regulating biotypes and harmful populations which, taking into account the specific environment and their dynamics, uses all techniques and methods, adapted in such a way as to be compatible and to maintain pest and pathogen populations at levels where they do not cause economic damage. Thus, integrated plant protection represents a system of regulation of biocenosis by correlating and interacting factors: plant, pest, pathogen, technology and environment, which resides in the holistic approach of sustainable agriculture oriented to the prevention and long-term control of phytosanitary agents to the combination of various techniques such as biological control, habitat manipulation, modification of cultural practices and use of resistant varieties [14].

Ensuring these desiderata is indispensable linked to methods and procedures of control, which need to be selected and applied in a manner that minimizes risks to human health, beneficial and non-target organisms and the environment, thus becoming applicable to all forms of agriculture, whether conventional, ecological or regenerative, with maximum use of natural mechanisms for regulating population densities of plant protection agents.

The achievement of the principles and objectives of integrated pest management requires, in addition to deep knowledge of the peculiarities of relations between phytosanitary agents and useful organisms, strict compliance with technological requirements for the application of phytosanitary means and production of protected crops.

It is indispensable to determine the triggers against the background of the in-depth analysis of the phytosanitary status and to establish the economic threshold of harm and to apply electronic means of collecting information and developing rational control schemes. It is necessary to mention that integrated plant protection is achieved within the agroecosystem, but not of an occupied batch of agricultural crops, and pest species should not be eliminated, but kept at a low level. The economic importance of each species and the level of losses that could be produced must be known. Ecological and economic data have shown that most species recognized as harmful do not need to be treated.

A primary role is played by abiotic factors: temperature, humidity, light, chemical factors and biotic factors, as well as intraspecific and interspecific relationships, which considerably influence the evolution of populations of harmful organisms. Each abiotic factor has a lower threshold and an upper temperature threshold, humidity, which, once exceeded, stops the multiplication of phytosanitary agents. Plant protection products shall only be used after monitoring indicates that they are necessary and treatments are made with the aim of eliminating only the target pest.

Implementation of postulates plant health, unlike the use of plant protection concepts, applying contemporary achievements of controlling the density of populations of harmful organisms, is oriented to the permanent assessment of phytosanitary status of agricultural crops following their monitoring, which is the foundation for preventing and discouraging the strong development and expansion of their population. On the basis of the information gathered and the particularities of host plants, in particular their degree of resistance to harmful organisms, schemes and methods of action shall be developed with the application of ecologically harmless means of control, taking into account the financial efficiency of the protection system and the yield of the crop and agricultural household.

CONCLUSIONS

The frequent manifestation of phenomena related to threats to plant health represent complex challenges that threaten not only population health, but also various indicators of plant productivity, soil health and global prosperity. The efforts of specialists aimed at protecting plants against the action of harmful organisms contribute not only to increasing food security and safety, but also to protecting the environment, alleviating poverty, reducing the impact of climate change, as well as stimulating economic development.

Increasing the productivity and profitability of agriculture is an essential direction in ensuring food security, which in the conditions of climate change requires the application of the most promising and effective biotechnological methods and methodologies, because climate change is becoming more and more important. It thus becomes evident that raising awareness of the importance of plant health among agricultural producers and decision makers becomes crucial.

As effective measures in promoting plant health, it is proposed to apply the link between soil, plant and human health, the role and place of GMOs in solving phytosanitary problems, the perspectives of genome editing, the expansion of the implementation of regenerative agriculture.

The article describes the role and place of several factors: link between soil, plant and human health, the role and place of GMOs in addressing phytosanitary issues, prospects for genome editing, activities to extend the implementation of regenerative agriculture, synergic phenomena as direction to increase the effectiveness of plant protection means and other phenomena that determine food security and food safety.

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Прогрес у галузі охорони здоров'я рослин для підвищення продовольчої безпеки

В умовах посилення впливу фітосанітарних агентів та поглиблення екологічних проблем, спричинених боротьбою з ними, раціональною стає зміна парадигми захисту рослин з орієнтацією на їх здоров'я. Мета роботи — висвітлити та встановити роль основних чинників, які є базою здоров'я рослин, та як вони визначають фітосанітарний стан агроекосистем і ступінь продовольчої безпеки. Методика та методологія досліджень орієнтовані на ідентифікацію та визначення біологічних особливостей агентів, а також на біологічний, екологічний та економічний аналіз засобів захисту сільськогосподарських культур. Як ефективні заходи у зміцненні здоров'я рослин пропонується застосовувати зв'язок між здоров'ям ґрунту, рослин і людини, роль і місце ГМО у вирішенні фітосанітарних проблем, перспективи змін генома, розширення впровадження відновлювального землеробства. З метою подолання цієї проблеми в статті наведено інформацію про можливості застосування синергетичних явищ у захисті рослин, взаємодія між якими забезпечує значне підвищення показників ефективності та стабільності стану системи. Описано роль і місце низки факторів: зв'язок між ґрунтом, рослинами і здоров'ям людини, роль і місце ГМО у вирішенні фітосанітарних проблем, перспективи змін генома, діяльність з розширення впровадження відновлювального землеробства, синергетичні явища як напрям підвищення ефективності засобів захисту рослин та інші явища, що визначають продовольчу безпеку і безпеку харчових продуктів, досягнення інституту в розробках і впровадженні біологічних засобів захисту рослин, особливо біологічних препаратів.

біопестициди; екологічне землеробство; шкідники; здоров'я рослин; синергетичний ефект; сталий розвиток

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