ORGANIC AND REGENERATIVE AGRICULTURE FOR SOLVING PHYTOSANITARY AND ECOLOGICAL PROBLEMS

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Abstract. *Against the background of strengthening food security and reducing damage caused by harmful organisms, the impact of which reaches 25-30% or completely compromises agricultural crops, the need to develop effective means of combating them has become urgent. In response to the increasing impact of ecological problems and the worsening of food security and food safety, the FAO UN declared 2020 the "International Year of Plant Health". This represents a unique opportunity to raise global awareness and integrates harmoniously into the "One Health" concept and contributes to ending hunger, reducing poverty, protecting the environment and stimulating economic development.*

Key words: food security, food safety, one health, plant health, plant protection.

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Introduction

Harmful organisms (insects, fungi, bacteria, weeds) cause major economic damage by reducing growth, decreasing crop yields, altering product quality and, in extreme cases, plant death, affecting food security and disrupting natural ecosystems, through the introduction of invasive species and loss of biodiversity, with a global impact.

Given the frequent manifestation of the contradiction between the role of plants in the biosphere and their protection functions, the need to change the plant protection paradigm, which as a widely accepted mental construct, has provided the human community with a consistent basis for the substantiation of the new paradigm “Plant Health”. Applying the appropriate defining apparatus, the spectrum of clear notions, the range of theoretical and practical visions oriented to solving the emerging problems, it becomes necessary to modify the institutional framework and the components in the structure of technological, extension and educational strategies [2]. Given the special role of plants, their health is a vital factor in supporting human and animal health and a special component in

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maintaining optimal soil and ecosystem functioning. For these reasons, the United Nations has declared 2020 the International Year of Plant Health [5].

The need to change the paradigm regarding plant protection, substantiated by scientists and accepted by human society based on the practice of research and practice "Plant Protection", which although has reached the stage of maturity, does not have sufficient theoretical and applied arguments for solving problems, making it rational to change the paradigm by introducing the phrase "Plant Health". The paradigm is based on recognized scientific achievements, which for a period of development of the investigated field, will provide original approaches to problems, as well as model solutions of specialists, accepted by social communities. As a result, models for formulating and solving problems will be offered to researchers, practitioners and the broad masses of the population, which include elements of a theoretical, instrumental and methodological nature, as well as various practical solutions [9].

Protection of agricultural crops from phytosanitary agents and preservation of their health capabilities is more cost-effective than emergency interventions, when plants are at a high level of attack by harmful organisms. Pests and disease pathogens are often impossible to eradicate once they have established themselves in crop agrocenoses, and their management is costly and time-consuming. Prevention is essential to avoid the devastating impact of pests and diseases on agriculture, livelihoods, food security and food safety [4].

The systemic approach combines different management strategies and practices to develop healthy crops while minimizing the use of pesticides. Avoiding the application of chemicals to eliminate harmful organisms not only contributes to improving plant health and reducing pesticide pressure, but also protects the environment by protecting beneficial organisms, especially entomophagous and pollinating insects, which are natural enemies of pests. There are still various responsibilities that fall to people: reducing and avoiding the transportation of plants and plant products, transferring harmful organisms to new areas, and decision-making and executive bodies must increase their support at national or regional level for plant protection organizations [7].

Although impressive indicators are recorded in the promotion of organic agriculture worldwide (this type of activity already reaches 50% of conventional agriculture), the functionality of agricultural operators and businesses in the agricultural field has been and remains ensured based on the extractive model through the intensive exploitation of natural resources, the creation of products and the generation of profit. The manifestation of extreme weather phenomena, the increase in the impact of many destructive factors (pollution, reduction of biological diversity, increased frequency

and intensity of phytosanitary agents), causes various social disorders and a decrease in the feeling of well-being of employees. An aggravating state is established in the current type of management and it becomes evident that the extraction model of human activities is no longer sustainable, which determines the need to implement modern approaches [1]. The perspective of survival is scientifically substantiated by expanding towards the way of regenerating natural resources and creating a healthier economy, society and planet.

Materials and Methods

For the isolation and identification of microbiological agents, protocol methods in microbiological and virological research were applied and adapted to the objects used in the processes of developing microbiological plant protection products [6].

The development and improvement of technological production processes were carried out with the application of in vivo and in vitro cultivation, using the production of biological agents on the surface, in depth and mixed, as well as the application of phytophagous insect lines to obtain biomass of entomopathogenic microorganisms (entomopathogenic viruses and bacteria).

For the quality control of biological agents and products in the process of production, storage and application, microscopic methods, physicochemical and molecular-biological methods were applied, as well as testing in laboratory conditions and in the field of experience of microbiological plant protection products [1].

The study represents a multidimensional approach to information in the field of the "One Health" concept, oriented towards solving ecological problems and the prosperity of agricultural businesses, using the inductive method, with a consistent basis in the analysis of specialized bibliographic resources.

Results and discussions

Changing the paradigm of plant protection – a result of human unrest and a way to solve the problems of agriculture, public health and environmental protection

Over the past decades, agriculture has been increasingly shaped by climate variability, the action of biotic and abiotic factors, the increase in the frequency and intensity of the action of harmful organisms, demographic pressure, resource constraints and economic uncertainty.

The increasing impact of harmful organisms against the background of climate change and the increase in their prevalence through the manifestation of various

difficulties, emphasizes the role of technological processes for the production and protection of agricultural crops.

Climate change and extensive agricultural activities have affected ecosystems, reduced biodiversity and creating new niches for the uncontrolled development of phytosanitary agents, accelerating the spread of harmful organisms on Earth and increasing their impact on the yield of phytotechnical activities and the environment [9].

Reduced attention to plant protection actions and unfavourable climatic conditions have created serious economic and ecological problems, determined by the considerable increase in the density and degree of damage of various species of pests and pathogens of cultivated plants (Table 1).

Table 1. Impact of pests in agriculture

INDICES	IMPACT IN DIFFERENT REGIONS			
	On Earth	CIS	Republic of Moldova	
			<1990	>1990
Pest species: Pest insects Pathogenic fungi Phytopathogenic bacteria Phytopathogenic viruses Weeds	21,000 8,000 6,000 2,000 1,600 800	1,500 600 400 200 100 100	600 130 200 120 100 50	600 140 200 120 100 50
Periodicity of uncontrolled risks	Locally every year	2-4 years	Pathogens – 2-4 years Pests – 5-7 years	Pathogens – 2-3 years Pests – 4-5 years
Volume of pesticides	15 million t.	750,000 t.	46,000 t.	2.5-3 thousand t.
Expenditure on pesticide application: Brazil, USA (FAO, 2025)	$14.3 billion $13.3 billion	The application of widely used pesticides in the global plant protection system costs $1.4-2.2 trillion annually (2-3% of global GDP) and $0.6 trillion to the environment. (Sust. Pulce, 10 Dec. 2025)		
Losses caused	$185.0 billion	-	-	2.5 – 3.0 billion lei

The information presented confirms the conclusion of the UNESCO Report (IAASTD Commission) on the lack of development prospects for traditional agriculture and the need to implement new directions of agriculture based on natural circuits (Paris, UNESCO, April 15, 2008).

The increase in losses caused by harmful organisms against the background of climate change, which lies in the modification of the invasive and epidemiological characteristics of phytosanitary agents, increases the prevalence of pathogens of diseases and harmful arthropods through the presence of various difficulties in carrying out technological processes for the production of agricultural crops.

Plants provide us with air, food and an optimal environment, and starting from the threats to plant health, which also represent a threat to human well-being and prosperity, which determined, according to the decision of the UN General Assembly, the designation of 2020 as the International Year of Plant Health. Recognizing that maintaining plant health protects the environment and biodiversity from plant pests, the concept addresses the effects of climate change and supports efforts to reduce malnutrition and stimulate economic development, and plant health is a key factor in strategies to eliminate rural poverty [5].

Over several decades of activity, accumulating a considerable body of theoretical and applied results, we have demonstrated the possibility of applying natural mechanisms to regulate the density of populations of harmful organisms. This represents a significant contribution to achieving high indicators of the quantity and quality of agricultural crops, which is an indispensable element for strengthening the "One Health" concept aimed at preserving the balance and overall health in the biosphere [9].

Organic farming differs in essential aspects from conventional production. In plant cultivation, organic farming tends to preserve the natural basis of agricultural production in the long term, which is regulated by law. Currently, in the Republic of Moldova, the regulatory framework in the field of organic agri-food production is reflected primarily by Law No. 115-XVI of 09.06.2005 on organic agriculture, which transposed the provisions of European regulations, and for the approval of activities in 2023, Law No. 237 adopted the requirements for obtaining and labeling organic products [14].

In response to the increasing impact of environmental factors, the scientific community is taking a separate and integrated approach, recognizing the interdependence between human, animal, plant, soil and ecosystem health. This approach emphasizes the need for collaboration between various fields to address health challenges and prevent or manage zoonotic diseases, antimicrobial resistance, serious phytopathogenic phenomena, soil fatigue and other threats to global health [7].

On the path to solving phytosanitary and environmental problems, only by approaching and applying natural mechanisms, applied in organic and regenerative agriculture systems, it becomes possible to develop intensive organic farming systems, which, thanks to the effects of management on human, animal, soil and plant health, are the basis for understanding the possible links between soil, animal, plant and human health and are the key to improving the quality and safety of food grown in all agricultural systems [3].

The need to initiate scientific research in the field of plant health is determined by the impact of harmful organisms, which is manifested by annual losses of 40% in global food production. With the scarcity of land, the intensification of agricultural production becomes the main option available to ensure food security. Well-managed ecosystems are essential for creating a healthy agri-food resource base. Achieving this goal requires increased investment in research and communication capacities that focus on plant health [6].

Plant health is increasingly recognized as a vital part of the “One Health” concept, which, although there are some conceptual gaps, related to poor integration in practice, especially in the manifestation of zoonoses and antimicrobial resistance, which requires the recognition of plant health as an essential factor in achieving its objectives by optimizing the health of people, animals, plants, soil and the environment.

The “One Health” Concept from the Perspective of Agricultural Sciences

The “One Health” concept has been approved as a fundamental solution, representing a global strategy to expand interdisciplinary collaborations and communications in all aspects of human, plant, domestic animal or wildlife health, which can no longer be addressed separately, but only jointly, integrally. One Health has been defined as an integrated approach that aims to sustainably balance and optimize the health of people, animals and ecosystems. The concept refers not only to concerns related to harmful organisms that occur in humans and animals, but also to aspects related to lifestyle, diet, the impact of different types of human-animal-plant-soil relationships and environmental exposures that can affect all population categories. To achieve the expected effects, it becomes necessary to educate the population, oriented towards knowledge and awareness of the effects of risk factors and the benefits of prognosis, but also communication and understanding between patients and health service providers [2, 7].

The term is essential in that agricultural sciences can draw attention to the need to consider the health of plants and their microbiome as a whole within the framework of the "One Health" concept, closely linked to the health of soil, plants, animals and humans. In the context of agroecological production based on

the sustainable management of natural resources, integrated pest management has been promoted to reduce the use of pesticides and mitigate negative effects on human health and the environment.

The "One Health" concept recognizes that all types of health are closely interconnected, which implies the application of a coordinated multidisciplinary and intersectoral approach to identify existing or potential risks that arise at the interface between the integrated "soil - plant - animal - human" system and natural and anthropogenic ecosystems. The activities are based on the design and implementation of programs, policies, legislation and research carried out in a coordinated manner by specialists involved in human, animal, plant, environmental and environmental health to achieve more valuable public health outcomes and to address challenges, which are progressing [10].

In addition to affecting food safety, the spread of mycotoxins produced by representatives of the Fusarium, Aspergillus and Penicillium fungi in plant-based foods is increasing, posing a major threat to human and animal health [11]. Agrochemicals can also have a negative impact on the environment. This concern has led to the search for alternative strategies, based on the One Health concept. We note in the context of agroecological production based on the sustainable management of natural resources (soil, water, air, biodiversity) that integrated plant protection reduces negative effects on human health and the environment.

Plant pests and disease pathogens, often overlooked until the emergence of plant pandemics, cause significant crop losses, food and feed insecurity and disruption of livelihoods. The use of pesticides for plant protection poses health risks, causing numerous cases of human and animal poisoning and the accumulation of chemicals in food of animal origin. Pesticide pollution in air, water, soil and ecosystems creates major health hazards for biodiversity and people. Pesticide resistance amplifies these threats, as it can lead to the application of higher doses, more toxic products and dangerous mixtures. Strategies for managing resistance exist, but this requires stronger integration between agriculture and public health to address risks related to food security, food safety, public health and environmental sustainability. Mycotoxins in staple crops pose significant risks to human, animal, soil and environmental health [6].

Plants and their health underpin ecosystem health. Unhealthy crops lose their efficiency in sequestering carbon, reduce soil fertility and increase erosion risks. There is ample evidence of the impact of plant health on other areas of health. Given the ubiquity and epidemic or pandemic potential of zoonoses, we note that they represent a compelling case for the need for collaboration between human, animal and soil health disciplines.

Given that plant health is currently included in the "One Health" concept, it should be noted that any activity related to human, animal, plant, soil and environmental health determines the need for cooperation between specialists responsible for the health of these biosphere elements. This demonstrates the additional benefits of addressing the health of people, animals, plants, soil and ecosystems, which highlights the reality that plant health is an integral part of the "One Health" concept.

Biological Plant Protection – an indispensable element for strengthening the "One Health" concept

The multi-year scientific research activity was the basis for the accumulation of significant scientific batches for the development of modern biotechnologies aimed at increasing and improving agri-food production, increasing the degree of application of mechanisms and natural resources with higher yields and high indicators of resilience to harmful organisms, protecting the environment and reducing the impact of climate change. As a result, it was demonstrated that this improves the situation in agriculture and contributes to ensuring food security, proposing innovative solutions and new directions for reducing the impact of the challenges manifested over the past decades. Very relevant are the achievements recorded in the field of biological plant protection (entomophages, biological preparations, biologically active substances) related to the use of natural mechanisms, excluding synthetic means with respect for the environment and promoting organic agriculture [11].

From climate change to antimicrobial resistance, many of the threats to health and well-being that human activity faces are linked to unsustainable patterns. The promotion of the "One Health" concept demonstrates that these threats can only be addressed through multisectoral and transdisciplinary collaboration in the fields of human, animal, plant and ecosystem health. The following recognized achievements contribute to this:

• Development of technological processes for the production of 15 entomophages, especially those applied in crop protection in protected areas;

• Selection of promising microorganisms and development of technologies for the production and application of microbiological agents to combat harmful organisms and the approval of 16 biological preparations based on them;

• Identification and synthesis of sex pheromones of 18 species of harmful insects and development of schemes for the original synthesis of pheromones of 72 species of insects and technological processes for their production and use for monitoring, mass capture, sterilization and disorientation of harmful insects.

Based on the recorded achievements and in accordance with the concept of "One Health", a huge amount of information has been accumulated on the application of the named means to an impressive range of crops, controlling the density of populations of harmful organisms, recording attractive levels of profitability of agricultural crops [12]. Prevention, detection and development of ways to respond to health threats has become real only by using the interconnections between human, animal, plant and ecosystem health. The concept, as an integrated approach, recognizes the interdependence of human, animal, plant, soil and ecosystem health and the interdependence between them.

At the global level, the "One Health" concept is a worldwide strategy to expand interdisciplinary collaborations and communications in all aspects related to health care of all biosphere elements. In order to achieve the main objectives and achieve the expected effects, it becomes necessary to develop and implement effectively promotional and educational policies regarding awareness of risk factors in this area.

Regenerative approach aimed at increasing the sustainability of production and business prosperity

Determining the future paths of agroecosystems and the biosphere is indispensable in relation to the regeneration capacity of ecosystems based on the natural possibility of their renewal and healing. This is determined by the ability of human society to move from the extraction mode of economic activities to the regeneration one. The foundation of such an approach is represented by regenerative thinking, as a philosophical way for agriculture aimed at creating systems capable of self-reproduction and based not only on the capabilities of generating financial profit, but also ensuring ecological, social and human resilience [7].

Research results have shown that the application of regenerative ecological practices contributes to the improvement of soils affected by various anthropogenic factors, catalyses carbon sequestration and increases the capacity to restore biodiversity, as well as maintains the dynamic balance between harmful and beneficial organisms, strengthening plant health. It is worth noting that this is also manifested by changing the extractive type of the company and increasing their sustainability, switching to regenerative production practices. By transferring part of the profits into regenerative capital, companies participate in financing ecological restoration projects, initiatives aimed at increasing the well-being of enterprises and solving ecological problems, thus switching to the regenerative type of production [6, 8].

On the way to the regenerative mode of production, the implementation of the principles of the circular economy is currently being recorded (designing sustainable activities, reusing enterprises and offering ecological products and services, strengthening businesses aimed at improving environmental health, facilitating activities in the field of organic agriculture). Thus, the stimulation of the transfer of extractive enterprises within the framework of regeneration agents, in economic and ecological systems is recorded. These practices not only restore ecological and social systems, but also contribute to the establishment of more resilient businesses [13].

We note that regenerative systems do not offer instant returns, they, by promoting the active resilience of the constituent elements, do not advance towards extracting efficiency, but rather strengthen regenerative businesses. Organizations established through regeneration will create more vigorous economies and societies within healthier ecosystems.

Conclusions

The damage caused to phytotechnical crops by harmful organisms constitutes 25-30%, and under the conditions of epiphytotic development of pathogens and invasions of pests and weeds, crop losses exceed the level of 50-60% or they completely compromise agricultural crops, and plant health is threatened by representatives of plant harmful entities. Perspectives on integrated pest management are a primary source of reliable and updated information on a wide range of topics of interest and importance for practitioners in ensuring integrated protection of agricultural crops. An essential first step in addressing pest or disease outbreaks is understanding the relevant biology, thus allowing the identification of aspects that can form the basis for the design and optimization of control approaches. It is tempting to hope that the emergence of artificial intelligence techniques could provide the potential for in-depth and training models to improve the accuracy of assessments of determining the appropriate dynamics of the expansion of frequency, areas of spread and intensity of development of harmful organisms.

The recorded results and the advancement of concepts for the development and application of biological protection of plants in strengthening the health of biological entities affected by the impact of harmful organisms reveal the driving forces behind a faulty protection system and propose a path oriented towards the establishment of true resilience of plants, animals, biological diversity and human health.

Incorporating plant health into One Health concept implies a stronger emphasis on ecological health through the trade-off between food security and planetary

boundaries. The concept of “One Health”, in addition to substantiating the multitude of natural mechanisms for strengthening human health, animals, plants, soil and ecosystems, highlights and implements deep knowledge for health specialists, students, as well as for the broad masses of the population. Analogous to a strategic plan, the concept plays a key role in generating knowledge and technologies, acting in accordance with the single health approach.

The interconnection between human, animal and environmental health has become increasingly evident in recent years, accompanied by global challenges, ecological disasters and climate change. This awareness requires a paradigm shift in the way we approach health and environmental issues.

Biogeocenotic regulatory mechanisms in natural ecosystems represent a perfect model for developing integrated plant protection systems. An example of the manifestation of these mechanisms is biological plant protection consisting of various alternative means to chemical ones (entomophages, biological preparations and biologically active substances). For their effective application, models for forecasting and monitoring the development of harmful organisms are proposed. The perspective directions of scientific research in the field of plant protection have been put forward and the role of organic agriculture in the national economy of the Republic of Moldova has been determined. Although not as developed as in other countries, this branch is already starting to concern Moldovan farmers.

This activity is a representation of how regenerative practices can solve various technological problems, heal humans, animals and the earth, support doctors, veterinarians and farmers in solving current problems and, possessing the capabilities and resources to use natural mechanisms, continue to build levers for approaching and solving health and environmental problems.

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