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BIOSHIELD

WORKSHOP REPORT

WORKSHOP OBJECTIVES

The subsequent phase of data collection centres around 1 local-level workshop organization conducted with academicians, industry representatives, associated partners and students. Workshops include discussion and brainstorming sessions regarding biotechnology response to global climate change.

Overview

- To specify the effects of global climate change and increasing disasters threatening biological life on the Earth, especially agricultural product yield.
- To clarify in which areas industrial and agricultural biotechnology has developed solutions so far and what their efficiency on a global scale is
- To reveal the future research and industrial and agricultural solution/remediation areas that can be developed through biotechnology
- To contribute to developing innovation in Biotech higher education towards upskilling students by delivering a curriculum
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PROGRAMME FLOW

01 **Opening**

Welcome and presenting workshop objectives

02 **Session 1**

Overview of Climate Change and Its Global Impact - Climate Change and Disasters' Effects on Agricultural Productivity

03 **Session 2**

Current Biotechnology Applications in Climate Change and Climate Change-Oriented Disaster Mitigation

04 **Session 3**

Promising Research Areas in Biotechnology and Role of Biotechnology in Disaster Resilience

05 **Session 4**

Discussion for Regional Variations in Climate Change Effects - Case Studies - Experiences

06 **Evaluation**

Participants'' Opinions on Workshop Organization

07 **Closing**

Participants'' Opinions on Workshop Organization

DATA COLLECTION METHOD

Data Collection Process includes document preparation for workshops, questionnaire preparation, stakeholder communication, workshop facilitation, quality evaluation survey design and implementation.

Participant Profiles

The eligible departments for biotechnology professionals: biology, chemistry, genetics, energy, biochemistry, molecular biology, ecology, geography, eco- remediation

The sector representatives can be from the following sectors by technique: genetic engineering, molecular breeding, molecular diagnostics and tissue culture.

Workshop Materials

We, all partners, contribute to developing workshop organization materials, presentations, and resources.

Know-how Exchange

Participants will exchange their know-how about climate change and resulting disasters, its effects on agriculture, current applications, and emerging research areas.

Workshop questions will guide participants to share their know-how, creative ideas and solution offers.

Workshop Outcomes

Case studies, and recommendations will be generated during the workshops.

Data Analysis

Data analysis includes demographic information about participants, themes created from the answers to the questions, highlights from each session, and quality evaluation results.

Participant Profiles

Participant Profiles	Academician	Sector	Associated Partner	Student
Number / Percentage	4/31	2/31	0	25/31

Participant Age

Age Range	18-25	26-35	36-45	46+
Number / Percentage	21/31	3/31	6/31	1/31

Gender

Gender	Female	Male
Number / Percentage	24/31	7/31

Data Analysis

Session 1

Questions of Session 1	**Themes**	**Sub-themes**	Excerpts of participants
Q1 **Do you think that in the current education in the field of biotechnology in Croatia there is a need for the development of specific skills needed to mitigate climate change?**	**1. Agriculture and food production** **2. Education about climate change** **3. Climate modeling, carbon trading** **4. Development of green technologies** **5. Waste management** **6. Bioinformatics**	1. Climate change directly affects plants and it is necessary to study/understand the impact of climate change on their growth and how to mitigate it. 2. Education	1. We need we need knowledge and skills related to sustainable agriculture and food production, or measures to mitigate the contamination of raw materials for food production as well as the environment. 2. Knowledge about the influence of high/low temp or drought/flood on the chemical composition of plants is necessary. 3. We need more skill from the area of food quality assurance and natural packaging solutions. 4. There are gaps in knowledge about which crops can withstand the weather (meteorological parameters), the development of ecological agriculture, bioremediation, etc. 5. Current education in the field of biotechnology in Croatia should focus on the development of specific knowledge and skills that contribute to mitigating climate change. First of all, it is important to ensure an understanding of climate change and its impact on biotechnological processes, including the basics of climatology, analysis of data related to climate change and assessment of the environmental footprint of biotechnological technologies. In addition, it is necessary to develop biotechnological processes aimed at sustainability, such as the production of biofuels, the use of microorganisms for bioremediation and purification of waste

		about climate change and integration of that topics in education system related to biotechnology 3. How to achieve a low carbon footprint using biotechnological processes 4. Mitigation of climate change due to sustainable waste manageme	water, and the creation of bio-based materials as a substitute for plastic. 6. Special emphasis should be placed on the engineering skills required for the development of green technologies, such as bioprocess design with a low carbon footprint, optimization of energy and resource consumption, and CO_2 capture and utilization in biotechnological production. The introduction of digital tools and modeling is also key, including the use of process simulation software, big data analytics and the application of artificial intelligence in sustainable technology research. 7. The development of the circular bioeconomy is another important aspect, which includes waste management, the use of by-products of biotechnological processes and the creation of sustainable supply chains. In addition to technical knowledge, it is crucial to foster interdisciplinary cooperation and communication skills, so that experts can effectively collaborate with other sectors, raise public awareness of sustainable practices and understand legislative frameworks related to climate change. Finally, education should include ethics and social responsibility, through assessing the impact of biotechnological innovations on the environment and society, while promoting responsible research and innovation. These skills would enable biotechnology professionals to actively contribute to sustainable development and the fight against climate change. 8. Waste management is an area that can significantly affect climate change, and therefore it is necessary to direct it to reuse, recycling, production of biogas, compost... 9. Bioinformatics should be used as a very important tool in the field of biotechnology that can help in dealing with climate change.

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Do you think that biotechnological solutions to mitigate climate change are sufficiently researched?			Not. Despite significant progress, research into biotechnological solutions for climate change mitigation remains insufficient, especially when considering the urgency of the global climate crisis. Although there are promising technologies, such as biofuel production, bioremediation and the use of microorganisms to capture carbon dioxide, their application often remains limited to the laboratory level or early stages of development. The lack of funds for research and investments in the transfer of technologies from the laboratory to the industrial level is a significant obstacle. In addition, certain aspects of biotechnological solutions, such as their long-term sustainability, energy efficiency and environmental impact, have not been sufficiently researched. For example, biofuel production may be associated with a negative impact on agricultural land and food supply, which requires additional studies to develop sustainable alternative methods. Also, a better integration of biotechnology into the wider systems of the circular economy is needed, as well as interdisciplinary research that would combine biotechnology with chemical engineering, informatics and environmental sciences. Finally, there is a need for greater focus on the adaptation of existing biotechnological solutions to specific climatic conditions and regional needs, as well as on the education of experts who will be able to develop and apply these technologies in practice. All this points to the fact that biotechnological solutions to climate change have enormous potential, but still require additional research and systematic support to become truly effective on a global scale.

Data Analysis

Session 1 – HIGHLIGHTS

1- Sustainable agriculture, food production and waste management using biotechnology tools can help in mitigate climate changes.

2- the development of biotechnological innovations to prevent and mitigate climate change should also be directed at the industrial level

Data Analysis

Session 2

Questions of Session 2	Themes	Sub-themes	Excerpts of participants
Q1 Do you know of any examples of technologies that rely on biotechnology that are already being used to mitigate climate change? Or some research projects dealing with that topic? If so, give an example.			• Bioremediation • For example, additives, especially of natural origin, which ensure the quality of food and thereby reduce its waste (either in distribution or at the household level) • Green infrastructure measures are multidisciplinary and are used to mitigate climate change. For example rain gardens, etc. • Using microorganisms to reduce CO2 • Biofuel production • Development of more resistant microorganisms for food production • GMO crops that withstand climate change • Yes, there are technologies that rely on biotechnology and are already being used to mitigate climate change. Some examples include the production of biofuels from biomass, which reduces greenhouse gas emissions compared to fossil fuels, the development of bioplastics that are biodegradable and can replace conventional plastic materials, and the production of chemicals using enzymes, which enables a more sustainable and energy-efficient process. • Personally, I have been dealing with these topics for many years and I am actively working on projects that deal with the production of biofuels,

			bioplastics and chemicals using enzymes. These projects are focused on the development of innovative and sustainable technologies that not only contribute to reducing the carbon footprint, but also encourage a circular economy. These examples clearly show how biotechnology can play a key role in the fight against climate change. • not on biotechnology, but I know that the HRZZ project TEMPHYS deals with the topic of the impact of climate change (specifically, high temps) on the chemical composition of plants.

Data Analysis

Session 2 – HIGHLIGHTS

1-Biotechnology is a broad field in which there are already various applications for mitigating climate change, and such research should continue to industry application.

Data Analysis

Session 3

Questions of Session 3	Themes	Sub-themes	Excerpts of participants
Q1 What emerging areas of biotechnology (eg, synthetic biology, CRISPR crop editing, microbial biofertilizers) are most promising for climate change adaptation and resilience, and how can they be incorporated into the curriculum?			All three have a good perspective in certain segments -- the development of plants (agricultural crops) resistant to the consequences of climate change as well as to diseases and consequently less use of pesticides, etc. Curriculum - new teaching units or entire courses, with laboratory exercises and perhaps demonstrations at certain relevant institutions. Production of various functional molecules through bio-fermentation (eg production of carnosolic acid, which is normally obtained by extraction from rosemary) and the like. Selection of cultivars resistant to overlooked climatic conditions. It is necessary to work on concrete tasks, the so-called case studies. Microbial biofertilizers. CRISPR technology. Agricultural improvements - development of more resistant crops.

			Microbial biofertilizers. Introduce them as discussions with students on the topic of climate change mitigation, showing examples of good practice,... In addition to the above, I would also mention genetic engineering as a promising biotechnology that is essential for dealing with climate change. Regarding the transfer of this knowledge through the curriculum in higher education, it is necessary to integrate interdisciplinary topics that combine biology, chemistry, engineering and informatics, because the development of these technologies requires the cooperation of different disciplines. The introduction of interdisciplinary projects, collaborative workshops and a "learning through problem-solving" approach would provide students with a holistic education and practical skills needed for climate change adaptation and resilience. Through this approach, the education system can prepare future experts to actively contribute to the development of sustainable biotechnological solutions.
What infrastructure needs (laboratory equipment, digital resources, field stations) need to be addressed to enable hands-on learning in biotechnology related to climate challenges?			We need better aboratory equipment, digital resources. Depending on the specific process, we need all of mentioned. Better IT equipment is needed. Digital resources and finance are missing. Laboratory equipment depending on the possibilities, but it is important where students see examples from practice - at the place of application. To enable practical learning in biotechnology aimed at solving climate challenges, in addition to the above (modern laboratory equipment, digitization and mathematical modeling...) cooperation with industry and research institutions is essential to ensure access to equipment and technologies that educational institutions often cannot finance themselves. Such cooperation allows students to participate in current research projects

			and gain experience with the latest technologies. The combination of modern laboratory equipment, digital resources and field opportunities would create a comprehensive educational system that would prepare students for the development and application of biotechnological solutions aimed at adapting to climate change.

Data Analysis

Session 3 – HIGHLIGHTS

1- There are emerging areas of biotechnology (eg, synthetic biology, CRISPR crop editing, microbial biofertilizers) that are promising for climate change adaptation and resilience

2- Financial resources are needed to equip the laboratory, but it is also necessary to show students examples from practice at the place of application.

Data Analysis

Session 4

Questions of Session 4	Themes	Sub-themes	Excerpts of participants
Q1 What specific skills related to digital tools (eg bioinformatics, climate data modeling) should be included in the biotechnology curriculum to prepare students for climate challenges?			Tools for predicting the consequences of climate change and testing different biotechnological solutions in virtual conditions. Modeling of climate data and programming but on concrete problems, not abstract learning of programming. Bioinformatics is already included, but its application must be expanded. Modeling of climate data - it is necessary to be more aware of where the data is and how to "read" it. In today's biotechnology education, in order for students to be prepared for climate challenges, it is crucial to incorporate specific digital skills that will enable them to effectively apply modern technologies in solving these challenges. The curriculum should include training in the use of software tools such as MATLAB, Aspen Plus and BioSolve for modeling biotechnological processes. These tools enable the analysis and optimization of biotechnological systems that can reduce CO2 emissions or increase energy efficiency. Basic programming knowledge, especially in languages like Python or R, is essential for data analysis, automation of biotechnological processes, and the

			creation of predictive models. Students should acquire skills in using software tools that enable automation of laboratory experiments and real-time monitoring of biotechnological systems, thus increasing efficiency and reducing human error. Also, it is important to include sustainability assessment tools, such as Life Cycle Assessment (LCA), so that students can assess the environmental impact of different biotechnological solutions. Finally, for better understanding of biological processes and simulation of real conditions, students should have the opportunity to work with virtual reality (VR) and augmented reality (AR). These tools can help visualize biotechnological processes such as photosynthesis or biofuel production, and allow students to gain a deeper understanding of these processes through interactive simulations.
How can universities and industry collaborate to develop interdisciplinary programs that combine biotechnology, climate science, and policy?			Through professional practices, workshops, research centers, etc. By involving students in specific projects of strategic importance for a particular industry; by collaborating on diploma theses, papers for conferences... They have to connect with private sector companies. Difficult without financial resources. Research projects. Investments in the education and training of experts. Organization of workshops. Through various projects, student practices. Cooperation between universities and industry is essential for the development of interdisciplinary programs that combine biotechnology, climate science and policy, as it enables the creation of educational programs that are relevant, innovative and aimed at solving real climate challenges. This cooperation can be achieved through several

			key steps. First, universities and industry can collaborate to jointly develop a curriculum that integrates biotechnology, climate science and policy, taking into account specific market needs and global challenges. Through this collaboration, industry can provide concrete guidance on the necessary skills and knowledge that students need to possess in order to meet the challenges of climate change, while universities can provide the theoretical framework and research foundations. This interdisciplinary approach enables students to gain a comprehensive understanding of how biotechnological solutions can help combat climate change, and how politics and regulations shape the implementation of these solutions. Another form of cooperation involves joint research projects between universities and industry that address specific challenges related to climate change. Through research and development of new technologies, industry can provide practical challenges and real-world conditions, while universities can offer access to advanced scientific methods and research. Such projects allow students and researchers to work on the concrete application of biotechnological innovations in the context of climate change, such as the development of sustainable biofuels, bioplastics or systems to reduce greenhouse gas emissions. Third, industry can provide student placements and internships in real industrial settings, allowing students to apply their theoretical knowledge to practical problems. These practices also allow industry to engage in the educational process, and provide feedback on how biotechnology and climate science can be implemented into industry practices, as well as how regulation and policy affect the development of new technologies. The last element of cooperation involves organizing joint seminars, workshops and conferences that bring together academic experts, industry leaders and decision makers. These events enable the exchange of ideas, experiences and best practices in the development of biotechnological solutions to climate challenges, and provide a

			platform to discuss the impact of policies on biotechnological innovations and their implementation. The university should send students to study in the industry, and the university in return does analysis for the industry.
How can we improve the transfer of research results in biotechnology to industrial practice for more effective mitigation of climate change? What are your recommendations and examples of good practice?			ex. through pilot projects. Regular meetings with the presentation of works. research results must be easy to implement and financially justified. Financing should be provided by the state. With the cooperation of academia, industry and politics. Investments in infrastructure in the field of biotechnology. To encourage students and scientists to cooperate with industry. Focus your thinking during lectures on possible application in practice. Improving the transfer of research results in biotechnology to industrial practice is essential for effective climate change mitigation. To achieve this, a better connection between academic institutions, industry and public institutions is needed, as well as securing support in the form of financial resources, political will and strategic partnerships. Academic research in biotechnology often focuses on basic science, but it is important that researchers think about the practical application of their results already in the research planning phase. This means developing technologies that have a clear potential for industrial implementation, such as biofuels, bioplastics, enzyme technologies to reduce emissions or pollution clean-up systems. Academic work should be focused on the identification of technologies that can directly respond to specific climate challenges and have the potential for commercialization.

			A stronger connection between researchers and industrial sectors is needed to ensure that research results are aligned with market needs. This includes the organization of joint working groups and knowledge exchange platforms between researchers, industry leaders and policy makers. Also, academic institutions should be able to identify specific industrial challenges that can be solved by biotechnological innovations. Governments and financial institutions can help transfer biotechnology research to industry by providing incentives and financial instruments that support the commercialization of innovations. This includes subsidies, tax breaks, as well as investments in start-ups dealing with biotechnological solutions to climate challenges. It is also important to support the development of incubators and accelerators that enable young companies to recognize the market potential of their solutions faster.
How to extend biotechnological research/results from micro to macro level?			Through the development of infrastructure -- production and others better connection between the private and public sectors. By financing them. Faculty and industry cooperation. International cooperation. Through the cooperation of industry and scientific institutions. Scaling up biotechnological research and results from the micro to the macro level is crucial for the successful application of biotechnological innovations in industry and society, especially in the context of climate challenges. At the micro level, biotechnological processes often give excellent results in controlled laboratory conditions, but to transfer these results to industrial production, it is necessary to optimize these processes for larger quantities. This entails adjusting conditions such as temperature, pH and pressure for large bioreactors, as well as developing processes to increase production volume while maintaining efficiency and sustainability. In

			addition, it is important to test new processes on a pilot scale, in semi-industrial plants, before the processes can be applied on an industrial scale. When biotechnological technologies leave the laboratory stage, it is necessary to adapt them to the conditions of industrial production. This involves integrating new technologies into existing production lines, so that biotechnological processes are compatible with existing machinery, equipment and quality control systems. Also, on a macro level, it is important to develop systems that can continuously and sustainably produce biotechnological products such as enzymes, bioplastics or biofuels that meet market needs. To transfer from micro to macro level, it is necessary to apply automation and digitization technologies, which improve the monitoring, control and optimization of biotechnological processes. Automated systems enable precise monitoring of parameters such as concentrations of microorganisms or chemicals in real time. Also, predictive modeling based on data collected in the laboratory enables better planning and optimization of processes on an industrial level. Cooperation between academic research centers, industrial partners and political bodies is essential for the transfer of biotechnological research into industrial applications. This cooperation may include joint projects, innovation clusters, incubators and start-ups that help identify the market potential of biotechnological solutions. Also, it is important to develop strategic partnerships that enable faster commercialization of innovations and their integration into industrial practice.
What role does public perception and acceptance of biotechnology play in its application to climate change mitigation? What are the potential ethical problems			Big, possible and crucial -- public information and education is needed to reduce the fear of the unknown, especially related to GMOs. we must constantly work on educating the public, who must be familiar with the positive and negative sides of the use of biotechnology. potential ethical problems must always be resolved to the benefit of the general public. Public perception is important and can only be solved by educating the population. Ethical problems arise from the danger of including in the biosystem new variables (eg gmo) that represent a potential danger for some of its components.

related to the use of advanced biotechnological tools in solving climate challenges and how can we solve them?			Public perception and acceptance of biotechnology play a key role in its application for climate change mitigation. Biotechnological innovations, although with the potential for significant environmental impact, face challenges related to social acceptance. Many people can be skeptical of new technologies, especially when they involve interventions in natural processes, such as genome modification or the use of genetically modified organisms (GMOs). Such fears often stem from a lack of understanding of biotechnological processes or from media reports that do not provide enough information about the safety and benefits of these technologies. For the successful transfer of biotechnological solutions into practice, it is important to involve the public in the decision-making process and educate them about the safety, benefits and possible risks of biotechnological interventions. Transparency in communication, information through scientific evidence, as well as engagement of all interested parties, including politicians, scientists, industry and citizens, can contribute to greater trust in biotechnological solutions. Also, it is important to ensure that the technologies used are aimed at improving the quality of life and protecting the environment, and not just for commercial gain. In terms of ethical issues, advanced biotechnological tools may raise concerns about potential negative consequences. For example, the use of genetically modified organisms in agriculture or biofuel production may raise concerns about their potential to spread outside of controlled conditions, leading to unpredictable ecological consequences. Also, there are concerns about ethical issues related to editing the genomes of humans or other organisms, which can open the door to potential misuse, such as the creation of biological weapons or the commercialization of genetic modifications in ways that are inconsistent with social norms. In order to solve these ethical problems, it is important to develop strong ethical guidelines and regulatory frameworks that ensure the safety and responsible use of biotechnology. This includes clearly defining the permitted limits for biotechnological interventions, harmonizing legislation with ethical norms and continuously monitoring

			the impact of new technologies on the environment and society. Also, it is necessary to engage the wider community, including bioethicists, sociologists and other experts, to ensure a comprehensive approach in considering the ethical aspects of biotechnological innovations. Applied responsibly, biotechnology can play a key role in mitigating climate change, but it is important to ensure that the development of these technologies goes hand in hand with ethical standards and social responsibility. Through educating the public, promoting transparency and responsible decision-making, it is possible to overcome barriers to acceptance and enable biotechnology to contribute to a sustainable solution to climate challenges. Synthetic biology and crop editing using CRISPR can produce very unintended/unforeseen results.

Data Analysis

Session 4 – HIGHLIGHTS

1- Greater connection between universities and industry can help facing climate change.

Quality Evaluation

Profession/Questions	Academician	Student	Industry representative	NGO representative	Other
Q1 (Occupation)	11,1%	77,8 %	5,6%	-	5,6%
Questions	Strongly Disagree	Disagree	Undecided	Agree	Strongly Agree
Q2				3 – 16.67%	15 – 83.33%
Q3				1 – 5.56%	17 – 94.44%
Q4				2 – 11.11%	16 – 88.89%
Q5				2 – 11.11%	16 – 88.89%
Q6				1 – 5.56%	17 – 94.44%
Q7				3 – 16.67%	15 – 83.33%

Comments

The participant distribution for the workshop was as follows: 11.11% of the participants were academicians, 77.8% were students (PhD and post-doctoral), and 5.6% were sector representatives and 5.6% were from other occupations.

• 16.67%of the participants agreed and 83.33% of them strongly agreed that the workshop was well-organized.
• 94.44% of the participants strongly agreed, and 5.56% agreed, that the discussions and shared information on the effects of climate change on agricultural product yields were valuable.
• 88.89% of the participants strongly agreed, and 11.11% agreed, that the discussions and information shared during the workshops on evaluating industrial and agricultural biotechnology solutions for climate change and disaster mitigation were valuable.
• 88.89% of the participants strongly agreed, and 11.11% agreed, that the discussions and shared information on future research areas and industrial solutions to climate change challenges in biotechnology were valuable.
• 94.44% of the participants strongly agreed, and 5.56% agreed, that the question-and-answer sessions were conducive to idea development and sufficiently comprehensive.
• 16.67%of the participants agreed and 83.33% of them strongly agreed that each participant was able to exchange information and ideas during the discussion.