Using biotechnology to preserve natural ecosystems: innovative approaches and technologies

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Abstract. In today's world, the preservation of natural ecosystems becomes an increasingly urgent task, requiring innovative approaches and technologies. This article examines the use of biotechnology in the conservation and protection of natural ecosystems. Various innovative approaches and technologies aimed at improving ecological sustainability and preserving biodiversity are discussed. Aspects such as the use of genetic engineering for the restoration of threatened species, bioremediation of polluted ecosystems, and the application of biological methods for pest control and soil protection are considered. This article provides an overview of modern advancements in biotechnology and their potential application for the preservation of natural ecosystems, as well as discusses the challenges and prospects for further development in this direction.

1 Introduction

Sustainability is widely recognized as a multidisciplinary concept that underpins "good agricultural practices (GAP)" in the field of agriculture, serving as a crucial element for ensuring adequate and reliable food production. Instead of viewing nature's resources as limitless, there is growing acknowledgment of the need to embrace and safeguard these valuable assets within the framework of sustainability. Sustainable agricultural system technologies (SAST) are among the primary solutions aimed at addressing the challenges brought about by industrialization. Bioremediation (BR) plays a significant role in these technological applications, utilizing various microorganisms and enzymes to partially or completely convert and eliminate pollutants. However, unresolved challenges necessitate the development of innovative and holistic approaches. Nanobioremediation emerges as a promising field offering natural, cost-effective, and sustainable solutions for addressing micro-pollution issues.

Furthermore, the integration of biotechnological applications with biomaterials science contributes to mitigating adverse effects and promoting the development of recyclable and biodegradable products. The convergence of smart technologies with material science,

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particularly nanotechnology, has led to advancements in various areas such as organic pollutant removal, sensor systems, and advanced detection methods, fostering sustainability in the agricultural sector. Additionally, the innovative perspective on fuel technology has led to the emergence of biofuel technology, offering an economically viable and ecologically sustainable alternative. The increasing adoption of hybrid and electric vehicles has further accelerated the production and modification of vehicles, promoting the use of biodiesel derived from non-food plant-based oils like microalgae.

In summary, interdisciplinary studies integrating nanotechnology, food materials tissue engineering, synthetic biology, and other fields in agriculture facilitate the development of economical, complementary, and biologically sustainable solutions. These efforts represent a crucial step towards safeguarding current and future ecosystems, promoting innovative, sustainable, and ecological practices.

Today, various challenges such as climate change, population growth, natural disasters, pollution, and the fast pace of life pose significant obstacles to the agricultural sector and food production. Additionally, limited understanding and incorrect implementation of sustainable development plans restrict the application of sustainability principles in various areas. To address these challenges and global issues, investments in technological innovations are rapidly increasing. The translation of theoretical knowledge into practical applications is becoming increasingly crucial for ensuring the continuity and protection of agriculture and food production.

Over the years, numerous in vivo and in vitro applications have been undertaken in agriculture and food production, leveraging modern biobased technologies (MBT) to enhance nutrient content, extend shelf life, increase product yield, and develop disease- and pest-resistant crops. However, with evolving lifestyles, the demand for cutting-edge technological solutions remains paramount. This review aims to raise awareness and provide a contemporary perspective by exploring the intersection of science, technology, and sustainability in agriculture and food production.

A multidisciplinary approach, coupled with the simultaneous utilization of MBT and innovative technologies, holds promise for effectively addressing current challenges and overcoming future difficulties. This comprehensive study is grounded in a well-defined classification system aligned with research objectives. By focusing on the impact of biotechnological advancements and innovative technologies on agricultural practices and food safety, this review seeks to highlight the transformative potential of MBT in ensuring sustainable food production.

The selection of this topic is motivated by the lack of holistic approaches in existing literature, particularly regarding the intersection of sustainability and biotechnology in the context of food production. It is anticipated that increased adoption of biological-based applications in agriculture will contribute to various areas, including food security, environmental pollution reduction, and plant disease management. This review underscores the importance of integrating biotechnological innovations with sustainable practices to address the complex challenges facing agriculture and food systems.

2 Research methodology

The review's literature selection process followed a rigorous set of criteria and guidelines. Firstly, the Web of Science, Springer, Science Direct, PubMed, and Google Scholar databases were utilized to identify scientific articles in English published in peer-reviewed journals, without imposing any restrictions on publication year. Secondly, keyword combinations relevant to the intersection of "sustainability," "agriculture," and "biotechnology," situated within the context of food safety and security, were employed to conduct the literature search.

After gathering a collection of over 4000 articles, a meticulous examination was conducted, and the articles were categorized based on predetermined questions related to the chosen keywords. Subsequently, they were classified according to whether they addressed specific approaches or applications. The resulting publications were then scrutinized, focusing on the central question of "How biotechnology can enhance food safety and security while promoting sustainable agricultural practices?"

Fig. 1. Keyword combinations grouped by extracting the relationship between publications through network mapping

Furthermore, the study adopted an "effect" and "correlation" perspective to ensure a comprehensive and balanced conclusion regarding the current state of knowledge and research in these domains. To enhance the reliability and precision of the information gathered, all publications were initially categorized based on keywords and then further refined based on databases containing interdisciplinary and top-quality publications. Table 1 was subsequently compiled from all articles relevant to the study's focal theme.

3 Results and Discussions

The systematic review process for food safety and security, within the context of contemporary biotechnologically based and sustainable agricultural practices, encompasses a broad field encompassing numerous distinct issues. Utilizing the schematic road map outlined in Table 2, developed within this context, specific keywords pertaining to various unique topics were identified and assessed by organizing and grouping them within the framework of the subject delineated within the scope of the compilation (Table 1). Industrialization stands as a pivotal force reshaping human development, economies, and technological landscapes. However, unchecked industrialization has facilitated the emission of unnecessary, often chemical-laden materials into the environment, posing significant threats to life and disrupting natural resource ecosystems. This surge in pollutants has

contributed to a proportional increase in diseases and environmental damage, exacerbating issues such as global warming, climate change, food scarcity, dwindling agricultural activities, population growth, urbanization, and migration. In particular, water, holding profound significance universally, has been profoundly impacted by industrial activities, leading to alterations in its physicochemical properties and the rise of pollutants, notably heavy metals, to its surface layers. Consequently, living spaces have been affected, with observable increases in trace metal levels reported. The release of toxic substances and heavy metals into the environment emerges as a paramount challenge confronting contemporary societies. Liquid waste, stemming from chemical leaks in domestic and industrial activities, infiltrates agricultural areas and underground water sources, leading to pollution of natural resources and water reservoirs. The accumulation of organic and inorganic residues from solid waste further exacerbates environmental pollution, giving rise to biological accumulations that pose significant challenges for both humanity and ecology. Chief among these challenges is the pollution of the environment with heavy metals, which not only directly impacts plants and animals but also affects humans through the food chain and alters soil structure.

Agriculture, being the primary source of food production, holds paramount importance in human nutrition. Recent years have witnessed a growing interest in plant-based foods, driven by their environmental friendliness, contribution to generational health and sustainability, and absence of ethical concerns associated with animal-based foods. Moreover, the agricultural sector plays a crucial role in economic and social development, serving as the primary source of income for many individuals and communities. Ensuring sustainability in agriculture is essential for achieving efficient, sufficient, and high-quality food supply, leveraging economically feasible inputs and outputs and environmentally friendly innovative technologies.

The concept of sustainability extends beyond agriculture to encompass various sectors interconnected with natural resources. Nonetheless, agriculture holds a significant position within this framework due to its unique characteristics. Originally aimed at safeguarding agriculture from the adverse impacts of industrialization, sustainability in agriculture now encompasses a comprehensive approach spanning production to consumption and beyond. In essence, sustainability in agriculture embodies a protective and enduring ethos that encompasses the entire agricultural ecosystem, from soil to table and beyond. Agriculture, as a scientific discipline fostering environmental protection through innovative and technologically-driven practices, faces various challenges that impose limitations on its efficacy. Factors such as earthquakes, erosion, disease and pest contamination, non-agricultural use, and cultural heritage preservation contribute to the decline in arable land for agricultural activities, compounded by the impacts of global warming. Consequently, the availability of fertile and healthy soil, along with plant biodiversity, becomes pivotal for sustainable food production, emphasizing the significance of agricultural land usability within the framework of sustainable agriculture.

The management of agriculture resembles a delicate balancing act, where sustainable development goals must be integrated. Sustainable agriculture encompasses three critical dimensions - economic, environmental, and sociocultural - offering a platform for multidisciplinary studies aimed at mitigating adverse environmental and health effects, revitalizing local ecosystems, and preserving biological diversity. In pursuit of progress and development, agriculture plays a foundational role within the broader context of sustainable development, encompassing ecological, economic, and social aspects, and relies on the applicability of innovative scientific outputs.

Human intervention, whether intentional or inadvertent, has led to significant alterations in the genetic makeup of agricultural products compared to their wild ancestors. These practices, prevalent in agricultural societies like Turkey, underscore the importance of

ensuring the sustainability of all agricultural components through a thorough understanding and adoption of technological advancements. Thus, staying abreast of technological developments and their effective integration is paramount for addressing challenges and fostering agricultural development.

4 Conclusions

In conclusion, agriculture stands at a critical juncture, facing myriad challenges ranging from environmental degradation to the loss of arable land and biodiversity. However, it also presents immense opportunities for sustainable development through innovative and technologically-driven solutions.

The review underscores the importance of adopting a multidisciplinary approach to address the complex issues facing agriculture. By integrating economic, environmental, and sociocultural dimensions, sustainable agriculture can mitigate adverse impacts on the environment and human health while promoting economic prosperity and social well-being.

Furthermore, the study highlights the need for continuous monitoring and adaptation to technological advancements to ensure the sustainability of agricultural practices. By leveraging innovative solutions and scientific outputs, agriculture can evolve to meet the demands of a rapidly changing world while preserving natural resources and biodiversity.

In essence, sustainable agriculture is not merely a goal but a continuous journey towards harmonizing human activities with nature. Through collaborative efforts and strategic interventions, we can pave the way for a more resilient, productive, and environmentally-friendly agricultural sector that serves the needs of present and future generations.

The modern world faces two significant challenges: ensuring food security and implementing sustainability practices in the face of climate change and population growth. This review aims to emphasize the importance of adopting a multidisciplinary approach and advancing technology and science to address current and future challenges. By integrating modern bio-based technologies with innovative techniques, we can effectively overcome many difficulties that future generations may encounter while achieving sustainability goals.

The review systematically examines the synergistic use of modern bio-based technologies and sustainable agricultural system technologies. Utilizing reliable databases, the review analyzed a substantial number of articles (>4000) to provide comprehensive insights into the subject matter. The relatively low publication content on "sustainability and biotechnology" highlights the need for further research and contributions to the literature in this area.

Furthermore, the review emphasizes the importance of developing a multidisciplinary perspective to address deficiencies in related fields and solve problems related to food safety and security sustainability. It underscores the critical role of protecting world food security as a crucial outcome of such efforts. Ultimately, safeguarding the sustainability of the world, food, and agriculture through innovative technologies and effective strategies is paramount for ensuring the continuity of healthy generations and the preservation of vital resources.

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