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Agricultural biotechnology and AI: Pioneering sustainable farming for the future

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ABSTRACT

Agriculture is encountering unprecedented obstacles such as climate change, limited resources, and the necessity for sustainable methods. This article examines how combining biotechnology and artificial intelligence (AI) can help solve these problems. Biotechnology, including technologies like GMOs, CRISPR-Cas9, and synthetic biology, provides means to create stronger crops, boost pest resilience, and increase resource efficiency. AI enhances these technologies by utilizing machine learning, predictive analytics, and robotics to improve crop management, track crop health, and predict agricultural results. The review showcases how AI improves data analysis for genetic modifications and fine-tunes crop management strategies, emphasizing the synergies between biotechnology and AI. AI technology has been used successfully in optimizing CRISPR and developing disease-resistant crops. Despite the progress made, obstacles remain, such as technical boundaries, ethical issues surrounding genetic alterations, and economic implications for small-scale farmers. Dealing with these obstacles demands a well-rounded strategy involving strong regulatory structures and collaboration with stakeholders. Potential next steps involve utilizing AI to improve precision breeding and integrating synthetic biology breakthroughs to enhance agricultural sustainability and productivity. Ongoing cooperation between biotechnology and AI is crucial for addressing current constraints and realizing a sustainable agricultural future.

KEYWORDS

Agricultural biotechnology; Artificial intelligence (AI); Climate change; Sustainable agriculture; Genetically Modified Organisms (GMOs)

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Introduction

Agriculture is facing crucial challenges from climate change, lack of resources, and the need for sustainable practices, at a pivotal moment in its development. The global farming industry is facing growing pressure from the harmful effects of climate variability, including changes in rainfall patterns, extreme weather events, and rising temperatures. These differences put crop production at risk, disrupt food security, and stress water resources, which are already strained by growing populations and agricultural needs. Adding to the complexity of these environmental pressures is the issue of limited resources [1]. Valuable resources such as arable land, water, and nutrients are diminishing quickly and intensely, making it more challenging to sustain current levels of food production. Moreover, conventional farming techniques are inadequate in addressing the challenges posed by climate change and population growth, thus requiring new and sustainable approaches. Moreover, excessive use of chemical inputs has resulted in soil deterioration and decreased biodiversity, posing a heightened risk to the sustainability of traditional farming practices.

In light of these urgent challenges, there is an increasing acknowledgment of the importance of creative, long-lasting agricultural methods. This review seeks to investigate the possibility of combing biotechnology and artificial intelligence (AI) as key answers to these problems. Biotechnology, through its progress in genetic modification and synthetic biology, holds the potential to create crops that can better withstand environmental pressures and utilize resources more effectively. At the same time, AI technologies such as machine learning and data analytics offer effective tools for improving agricultural practices, ranging from precision farming to predictive analytics for crop management. The aim of this assessment is to analyze the potential impact of combining biotechnology and AI in promoting a sustainable agricultural future [2]. This review will focus on how these technologies are transforming modern agriculture by exploring their current advancements, practical uses, and potential obstacles. Through this investigation, our goal is to clarify how these advancements can together help create a more durable and environmentally friendly farming system [3].

The Evolution of Agriculture: Biotechnological Approaches

Agricultural biotechnology uses scientific methods and tools to manipulate living systems and organisms in order to increase crop yields, enhance food quality, and tackle agricultural obstacles. It involves various techniques that use biological concepts in farming to create desirable traits in crops and improve agricultural practices. Genetically modified organisms (GMOs) are a major breakthrough in agricultural biotechnology. GMOs are plants that have been modified using genetic engineering to exhibit certain characteristics like immunity to insects, illnesses, or weed killers. For example, Bt cotton has been altered genetically to create a toxic protein for specific insects, lowering the reliance on pesticides and enhancing crop production [4].

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CRISPR-Cas9 is another revolutionary technology that enables scientists to make precise alterations to an organism's DNA. CRISPR has completely transformed genetic engineering by allowing precise alterations, like increasing resistance to diseases or enhancing nutritional value in crops. This technology has the ability to speed up the creation of new crop types with specific characteristics, dealing with issues related to productivity and resilience. Synthetic biology marks a new territory in the field of agricultural biotechnology. It requires reworking and building fresh biological components, gadgets, and systems. Scientists can manipulate crops to generate important substances or carry out new tasks by designing artificial pathways and organisms [5].

One application of synthetic biology is creating plants that can produce pharmaceuticals or biofuels, expanding the variety of agricultural products beyond just food crops. These advancements in biotechnology work together to improve crops, resist pests, and use resources more efficiently. GMOs and CRISPR technologies allow for the development of crops that are better able to withstand environmental pressures and require fewer chemical inputs. Synthetic biology creates opportunities to develop plants with improved characteristics or new uses, further bolstering the environmental friendliness of agriculture. Combined, these technologies provide effective solutions for modern agricultural challenges, promoting a more efficient and environmentally-friendly food production system [6].

Artificial Intelligence: An Overview

Artificial Intelligence (AI) includes various technologies created to mimic human intelligence functions, such as learning, reasoning, and self-improvement. AI has a significant impact in agriculture by utilizing machine learning and data analytics to provide advanced analysis and decision-making abilities. Machine learning, a branch of artificial intelligence, utilizes algorithms to learn from data and provide predictions. In the agricultural sector, this technology is utilized to scrutinize large quantities of data from diverse sources for enhancing farming techniques. Data analytics, another essential sector, entails analyzing big sets of data to discover patterns and insights, assisting farmers in making well-informed choices [7].

Important artificial intelligence technologies in the field of agriculture consist of predictive analytics, computer vision, and robotics. Predictive analytics uses past and current data to predict agricultural results like crop yields, disease spread, and weather trends. Computer vision employs image recognition methods to observe crop conditions and identify pest infestations, allowing for prompt actions. Robotics, which includes autonomous tractors and drones, takes over duties like planting, harvesting, and field monitoring, enhancing productivity and cutting down on labor expenses. AI's use in biotechnology goes beyond, as it boosts research and development [8]. AI algorithms have the ability to examine genetic information in order to pinpoint advantageous characteristics and forecast the results of genetic alterations. This merging of AI's data-driven insights with biotechnological innovation speeds up the advancement of genetically modified crops and improves biotechnological processes to boost agricultural productivity and sustainability [9]. So, AI's advancements in precision agriculture, crop monitoring, and yield prediction play a key role in improving efficiency, productivity, and sustainability in modern farming practices.

Integration of AI Technologies in Biotechnological Research

The merging of biotechnology and artificial intelligence (AI) is a strong convergence that greatly improves agricultural research and development. By merging these areas, scientists can utilize the advanced data analysis abilities of AI to achieve advancements in biotechnology. One key advantage of combining biotechnology with AI is the improvement of genetic modification data analysis. AI algorithms have the ability to analyze large quantities of genomic data quickly and accurately, pinpointing genetic indicators linked to positive traits like resistance to drought or diseases. For example, machine learning algorithms have been used to analyze gene expression data and forecast the results of genetic alterations, making the process of creating genetically modified crops with improved characteristics more efficient [10].

AI and biotechnology collaborate in another field - optimizing strategies for managing crops. AI-powered technologies, like predictive analytics and computer vision, can evaluate environmental and crop data to offer practical insights. These instruments aid in refining farming methods, like precision watering and focused pest management. For instance, AI technology has the ability to forecast the best times for irrigation by analyzing weather predictions and soil moisture levels, which ultimately leads to lower water consumption and higher crop production. The potential of this synergy is demonstrated by various successful projects [11]. An important instance involves the partnership of artificial intelligence and biotechnology to create disease-resistant crops. AI was utilized by University of Illinois researchers to study plant genomics data and pinpoint genetic variations linked to plant disease resistance. This study helped in creating crop varieties with improved resistance against diseases, showcasing the potential of AI in speeding up biotechnological progress [12].

Another instance involves utilizing AI to improve CRISPR gene editing methods. AI models have been created to forecast the effectiveness of CRISPR edits, decreasing off-target impacts and enhancing the accuracy of genetic alterations. The fusion of AI with biotechnology has resulted in improved genetic engineering processes, demonstrating the practical advantages of this collaboration. In general, the combination of biotechnology and AI improves the accuracy, productivity, and success of agricultural research and applications, advancing towards a more sustainable and productive agricultural future [13].

Navigating the Complexities of AI Integration in Agricultural Biotechnology

One major obstacle is the difficulty of combining AI with biotechnological procedures. AI systems need a large amount of good quality data to work well, and obtaining this data can be challenging because of the various and constantly changing characteristics of biological systems. Moreover, it continues to be difficult to guarantee the precision and dependability of AI models when predicting genetic results or crop productivity. Mistakes in AI forecasts might result in unexpected outcomes, like the creation of crops that have unforeseen weaknesses [14].

Ethical issues are also of utmost importance. Genetic modifications and AI-driven interventions prompt concerns regarding lasting effects on ecosystems and variety of species. Rigorous examination is necessary due to the possibility of

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unforeseen ecological impacts and ethical considerations when modifying plant and animal genomes through GMOs. The public's acceptance of GMOs and biotechnological innovations is a crucial concern, as there is frequently opposition based on worries about safety and environmental consequences. From an economic standpoint, incorporating AI and biotechnology can come with a high price tag [15]. Small-scale farmers or developing regions may find it challenging to afford the significant investment required for the development and deployment of advanced technologies. The differences in available technologies could worsen the disparities in agricultural productivity and economic stability between big agribusinesses and smaller farms [16].

The transition to AI and biotechnology in agriculture could result in job loss socially. Automation and AI-powered technologies may decrease the need for conventional agricultural workers, affecting job opportunities in rural areas. Moreover, worries arise regarding the accumulation of technological authority in a handful of major companies, potentially resulting in monopolistic behavior and control over food systems. Tackling these challenges necessitates a well-rounded strategy, which includes strong regulatory structures, continuous research, and involving all parties to guarantee that the merging of biotechnology and AI positively impacts all areas of society, while also addressing possible risks and ethical issues [17].

Future Growth and Opportunities in AI Farm Technology

The merging of AI and biotechnology is expected to bring about significant progress that will transform the agricultural industry. An upcoming trend is the use of AI in precision breeding methods. Progress in AI-driven phenomics and genomics is improving the efficiency of selecting and breeding plants with ideal traits compared to traditional techniques. This trend will speed up the creation of crop varieties that can better withstand climate change and diseases [18].

Another encouraging advancement involves combining AI with synthetic biology to modify microbes and plants for particular environmental conditions or agricultural requirements. For example, artificial intelligence is being utilized to create artificial routes in plants in order to enhance absorption of nutrients or generate biofuels, which could lessen dependence on chemical fertilizers and fossil fuels. Upcoming advancements also involve implementing AI-driven drones and sensors for instant monitoring and control of crops. These technologies will give farmers accurate information on the health of crops, soil conditions, and pest behavior, leading to more precise interventions and less wastage of resources [19,20]. In general, these progressions have the possibility to greatly improve agricultural sustainability, boost productivity, and decrease environmental harm, signaling a fresh age of intelligent and sustainable farming.

Conclusions

The merging of AI and biotechnology is expected to bring about significant progress that will transform the agricultural industry. An upcoming trend is the use of AI in precision breeding methods. Progress in AI-driven phenomics and genomics is improving the efficiency of selecting and breeding plants with ideal traits compared to traditional techniques. This trend will speed up the creation of crop varieties that can better withstand climate change and diseases [18]. Another encouraging advancement involves combining AI with synthetic biology to modify microbes and plants for particular environmental conditions or agricultural requirements. For example, artificial intelligence is being utilized to create artificial routes in plants in order to enhance absorption of nutrients or generate biofuels, which could lessen dependence on chemical fertilizers and fossil fuels. Upcoming advancements also involve implementing AI-driven drones and sensors for instant monitoring and control of crops. These technologies will give farmers accurate information on the health of crops, soil conditions, and pest behavior, leading to more precise interventions and less wastage of resources [19,20]. In general, these progressions have the possibility to greatly improve agricultural sustainability, boost productivity, and decrease environmental harm, signaling a fresh age of intelligent and sustainable farming

Disclosure statement

No potential conflict of interest was reported by the authors.

References

1. Jung J, Maeda M, Chang A, Bhandari M, Ashapure A, Landivar-Bowles J. The potential of remote sensing and artificial intelligence as tools to improve the resilience of agriculture production systems. Curr Opin Biotechnol. 2021;70:15-22. https://doi.org/10.1016/j.copbio.2020.09.003
2. Ashoka P, Devi BR, Sharma N, Behera M, Gautam A, Jha A, et al. Artificial Intelligence in Water Management for Sustainable Farming: A Review. J Sci Res. 2024;30(6):511-525. https://doi.org/10.9734/jsrr%2F2024%2Fv30i62068
3. Patel HM. The transformative role of artificial intelligence in modern agriculture. Rev Artif Intell Educ. 2023;4(00):e014. https://doi.org/10.37497/rev.artif.intell.educ.v4i00.14
4. Shikha D, Sindhura KA, Rastogi M, Saritha B, Satapathy SN, Srivastava S, et al. A Review on Propelling Agricultural Practices with Biotechnology into a New Era. J Adv Biol Biotechnol. 2024; 27(3):99-111. https://doi.org/10.9734/jabb/2024/v27i3725
5. Anderson JA, Gipmans M, Hurst S, Layton R, Nehra N, Pickett J, et al. Emerging agricultural biotechnologies for sustainable agriculture and food security. J Agric Food Chem. 2016;64(2):383-393. https://doi.org/10.1021/acs.jafc.5b04543
6. Yadav AN, Kumar R, Kumar S, Kumar V, Sugitha T, Singh B, et al. Beneficial microbiomes: biodiversity and potential biotechnological applications for sustainable agriculture and human health. J Appl Biol Biotechnol. 2017;5(6):45-57. https://dx.doi.org/10.7324/JABB.2017.50607
7. Adewusi AO, Asuzu OF, Olorunsogo T, Iwuanyanwu C, Adaga E, Daraojimba DO. AI in precision agriculture: A review of technologies for sustainable farming practices. J Adv Res Rev. 2024;21(1):2276-2285. https://doi.org/10.30574/wjarr.2024.21.1.0314
8. Elbasi E, Mostafa N, AlArnaout Z, Zreikat AI, Cina E, Varghese G, et al. Artificial intelligence technology in the agricultural sector: A systematic literature review. IEEE access. 202226;11:171-202. https://doi.org/10.1109/ACCESS.2022.3232485
9. Sharma S, Verma K, Hardaha P. Implementation of artificial intelligence in agriculture. Journal of Computational and Cognitive Engineering. 2023;2(2):155-162. https://doi.org/10.47852/bonviewJCCE2202174
10. Sheikh M, Iqra F, Ambreen H, Pravin KA, Ikra M, Chung YS. Integrating artificial intelligence and high-throughput phenotyping for crop improvement. J Integr Agric. 2024;23(6):1787-1802. https://doi.org/10.1016/j.jia.2023.10.019
11. O'Brien JT, Nelson C. Assessing the risks posed by the convergence of artificial intelligence and biotechnology. Health Secur.

https://doi.org/10.61577/jaiar.2024.1000010

2020;18(3):219-227. https://doi.org/10.1089/hs.2019.0122
12. Taneja A, Nair G, Joshi M, Sharma S, Sharma S, Jambrak AR, et al. Artificial intelligence: Implications for the agri-food sector. Agronomy. 2023;13(5):1397. https://doi.org/10.3390/agronomy13051397
13. Dixit S, Kumar A, Srinivasan K, Vincent PD, Ramu Krishnan N. Advancing genome editing with artificial intelligence: opportunities, challenges, and future directions. Front Bioeng Biotechnol. 2024;11:1335901. https://doi.org/10.3389/fbioe.2023.1335901
14. Tzachor A, Devare M, King B, Avin S, Ó hÉigeartaigh S. Responsible artificial intelligence in agriculture requires systemic understanding of risks and externalities. Nat Mach Intell. 2022;4(2):104-109. https://doi.org/10.1038/s42256-022-00440-4
15. Dara R, Hazrati Fard SM, Kaur J. Recommendations for ethical and responsible use of artificial intelligence in digital agriculture. Front Artif Intell. 2022;5:884192.
16. Harfouche AL, Petousi V, Meilan R, Sweet J, Twardowski T, Altman A. Promoting ethically responsible use of agricultural biotechnology. Trends Plant Sci. 2021;26(6):546-559. https://doi.org/10.1016/j.tplants.2020.12.015
17. Mishra AC, Das J, Awtar R. An Emerging Era of Research in Agriculture Using AI. J Sci Res. 2024:1-7. https://doi.org/10.61808/jsrt93
18. Das S, Kaur M, Chhabra V, Nandi T, Mishra P, Ghosh S. A Systematic Review of Artificial Intelligence: A Future Guide to Sustainable Agriculture. Int J Environ Clim. 2024;14(4):562-573. https://doi.org/10.9734/ijecc/2024/v14i44139
19. Pathan M, Patel N, Yagnik H, Shah M. Artificial cognition for applications in smart agriculture: A comprehensive review. Artif Intell Agric. 2020;4:81-95. https://doi.org/10.1016/j.aiia.2020.06.001
20. Mana AA, Allouhi A, Hamrani A, Rahman S, el Jamaoui I, Jayachandran K. Sustainable AI-Based Production Agriculture: Exploring AI Applications and Implications in Agricultural Practices. Smart Agri Technol. 2024:100416. https://doi.org/10.1016/j.atech.2024.100416

https://doi.org/10.61577/jaiar.2024.1000010