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Precision Agriculture and Human Health: The Biotechnology Connection: A Mini Review

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ABSTRACT

Precision agriculture uses biotechnological innovations to enhance crop productivity and sustainability and can influence human health. Genetically modified crops, microbial biofertilizers, and controlled-environment agriculture reduce pesticide reliance and improve nutritional value. However, unintentional exposure to modified plant metabolites, recalcitrant agrochemicals, and destabilized soil microbiomes may impact food safety and public health. This mini-review covers the double-edged impacts of precision agriculture on human biology, focusing on micronutrient bioavailability, chronic disease risk modulation, and microbiota modulation through diet. Utilization of omics-based technologies for crop engineering is viewed for the development of nutritionally fortified and hypoallergenic foods. Risk assessment models and policy recommendations are also examined for adoption safety. In connecting agrifood biotechnology to biomedical outcomes, this review emphasizes the need for an interdisciplinary approach in food-health-environment interactions.

Keywords: Precision Agriculture; Biotechnology; Nutritional Health; Microbiome; GMOs

Abbreviations: PA: Precision Agriculture; GPS: Global Positioning Systems; GIS: Geographic Information Systems; VRT: Variable Rate Technology; UAVs: Unmanned Aerial Vehicles; GM: Genetically Modified; GMOs: Genetically Modified Organisms; EFSA: European Food Safety Authority; FDA: Food and Drug Administration

Introduction

Precision agriculture (PA) refers to the application of advanced technological solutions to optimize field-level management of crop production. The core idea is the delivery of the right input, at the right time, in the right amount, and to the right location, thereby maximizing productivity, sustainability, and resource efficiency. Technologies such as global positioning systems (GPS), geographic information systems (GIS), variable rate technology (VRT), and unmanned aerial vehicles (UAVs) facilitate real-time monitoring and targeted interventions. Soil- and plant-based sensors detect moisture, nutrient levels, and crop health and transmit the information into AI-based algorithms that guide decision-making. These technologies reduce input waste, decrease environmental impact, and maximize yields. In addition, remote sensing and satellite imagery enable farmers to determine crop stress and disease outbreaks at an early stage, allowing responses in a timely manner. With PA maturing, it aligns more and more with the tenets of sustainable agriculture and food security (Ebadi, et al. [1-6])

Health-Enhancing Agricultural Biotech Applications

Contemporary agricultural biotechnology goes beyond yield increase to encompass the enhancement of human health. Crop biofortification with essential micronutrients such as iron, zinc, and vitamin A by genetic modification is a milestone towards eliminating global malnutrition. Beta-carotene-enriched Golden Rice is a great example of the contribution PA and biotech technologies can make towards combating vitamin A deficiency. Furthermore, genetically modified (GM) crops with higher tolerance to pests and diseases reduce the application of chemical pesticides, thereby reducing the risk of exposure to hazardous agrochemicals to farmers and consumers. Transgenic crops can even be utilized in the production of edible vaccines, offering a new avenue for prophylactic medicine. In the broadest sense, agricultural biotechnology with a health focus is redrawing the intersection point of agriculture and medicine, highlighting the need for integrated policy and research strategies combining food production and public health factors (Zare, et al. [6-8]).

Nutritional and Toxicological Health Impacts

Agricultural use of biotechnology raises pertinent questions about its nutritional and toxicological effects. Even though the nutritional content of biofortified foods seems to have the potential to reduce micronutrient deficiency, there remain concerns regarding allergenicity and unintended effects of transgenic modification. Furthermore, reduced pesticide use by biotechnology interventions does not entirely eliminate residual toxicity risk due to other agrochemicals. Chronic exposure to such toxins has been implicated in a series of diseases like endocrine disruption, carcinogenicity, and neurotoxicity. In addition, genetic alteration of food content can impact gut microbiota and metabolism but with long-term studies required to confirm such impacts. Thus, an intensive toxicological assessment process, including short- and long-term health tests, is mandatory before large-scale production of biotech crops.

Perception and trust on the part of the public regarding genetically modified organisms (GMOs) are also essential and must be addressed through transparent communication and regulation (Xu, et al. [9,10]). The Figure 1 graphically portrays significant health-associated impacts—favorable and perhaps adverse—attributable to the agricultural use of biotechnology. It depicts the manner in which biofortified crops can reduce micronutrient deficiency (high score), alongside other issues such as allergenicity, genetic modification, and residual pesticide toxicity, each representing varying levels of health importance. This relative visualization is important for policymakers, academics, and the public to weigh the benefits against potential dangers and highlights the need for robust safety reviews and transparency.

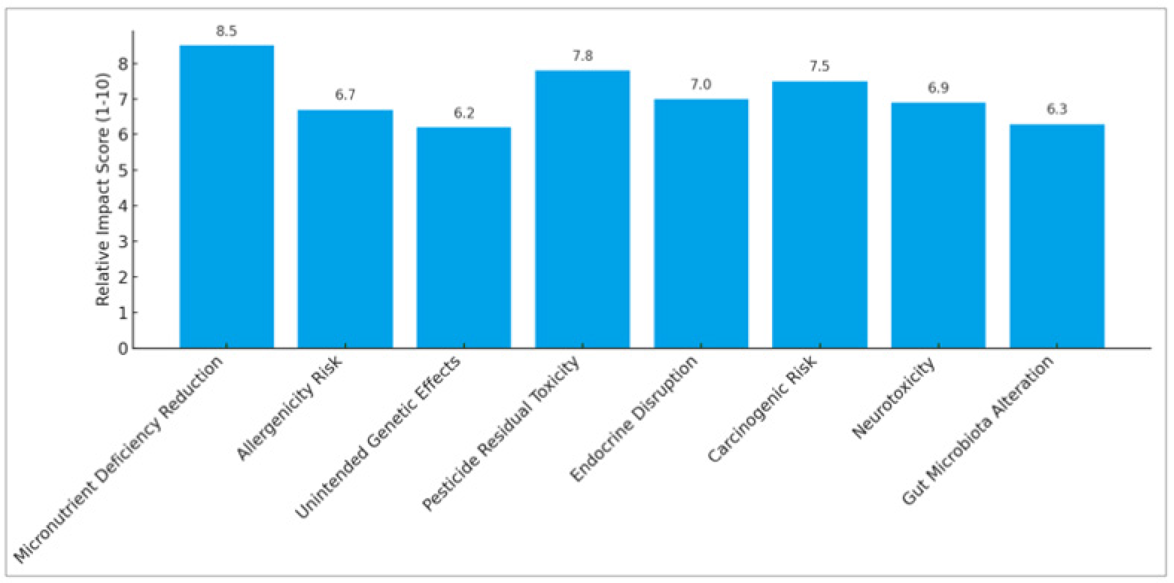

Figure 1: Nutritional and toxicological health impacts of biotechnology in agriculture.

Risk Assessment and Regulator Perspectives

Robust risk assessment models must balance the benefits and potential risks of biotech-based precision farming. Regulators such as the European Food Safety Authority (EFSA) and the United States Food and Drug Administration (FDA) have set standards for evaluating the safety of transgenic plants. The standards include determination of gene stability, allergenicity, environmental risk, and nutritional value. Yet, regulatory landscapes vary very considerably across countries and tend to reflect cultural and political attitudes to biotechnology. A science-informed evidence-based global harmonization would facilitate worldwide trade and enhance safety assurance. There is poor technical capacity for application of biosafety measures among developing nations and additional challenges created thereby. Besides, intellectual property rights issues involved with patented biotechnologies lead to issues surrounding access and equity, particularly to smallholder farmers. Innovative models of collaborative governance in the public-private partnership mode can facilitate inclusive innovation and ensure regulatory systems that incorporate technological progress and the public good based on Table 1 (Cheng, et al. [11-13]).

Table 1: Risk assessment considerations for agricultural biotechnologies.

Assessment Area	Key Criteria	Relevance to Health	Regulatory Body	Reference
Allergenicity	Protein similarity to known allergens	Prevent allergic reactions	EFSA, FDA	(Sharma [7])
Gene Stability	Consistency across generations	Ensures predictability	USDA, EFSA	(Ninomiya [8])
Environmental Impact	Gene flow, non-target effects	Maintains ecological balance	EPA, FAO	(Xu, et al. [9])
Nutritional Equivalence	Comparison with conventional crops	Maintains dietary safety	WHO, FAO	(Satyanarayana [10])
Long-term Toxicity	Chronic exposure studies	Assesses cumulative effects	National Institutes of Health	(Satyanarayana [10])

Toward Integrative Agri-Biomedical Policies

As agriculture, nutrition, and health are interlinked, integrative policies have become a growing necessity to bridge the gap between agronomic intervention and biomedical result. Agri-biomedical convergence envisions a policy space where agricultural innovation is evaluated not just for yield or financial gains, but also for the implications on human health and disease avoidance. Inter-sectoral partnership among ministries of agriculture, health, environment, and education can foster comprehensive approaches to policy-making. For example, promoting the development of nutrient-rich crops and reducing pesticide application aligns agricultural and health goals. Furthermore, data convergence from surveillance systems in agricultural monitoring systems and health can define patterns and inform interventions. Synergized with biomedicine, precision agriculture can potentially generate strong food systems that feed populations and reduce the disease burden (Table 2). Policy coherence, stakeholder involvement, and translational research will be drivers toward realizing the vision of sustainable, health-oriented agriculture in the future (Wang, et al. [14-16]).

Table 2: Technological tools in precision agriculture and their health implications.

Technology	Function	Health Benefit	Example	Reference
GPS & GIS	Site-specific field management	Reduced chemical overuse	Variable rate pesticide application	(Sharma [7])
Remote Sensing	Crop stress detection	Early intervention reduces crop loss	Satellite-based NDVI analysis	(Ninomiya [8])
Soil Sensors	Nutrient and moisture monitoring	Optimized fertilization	IoT-enabled soil probes	(Xu, et al. [9])
Genetic Engineering	Biofortification, pest resistance	Enhanced nutrition, lower pesticide exposure	Golden Rice, Bt Cotton	(Satyanarayana, [10])
Edible Vaccines	Delivery of immunogens through plants	Accessible disease prevention	GM potatoes with hepatitis B antigen	(Gaobotse, et al. [12])

Conclusion

Precision agriculture, driven by biotechnology, promises to improve not only crop yield but also human health. With biofortified foods to reduced pesticide exposure, its advantages are diverse; they are, however, accompanied by subtle challenges in the form of possible toxicological impacts, changes in the microbiome, and socio-regulatory issues. Equilibrium is vital to ensure that biotechnological progress in agriculture translates into secure, equitable, and health-directed food systems: it must rest on stringent risk assessment, cross-disciplinary synergies, and integrative policy.

References

1. Ebadi AG, Selamoglu Z (2025) Advances in veterinary medicine: Sustainable approaches to animal health management and disease prevention. Journal of Animal Biology and Veterinary Medicine 4: 1-13.
2. Ebadi AG, Hisoriev H (2018) Cladophora glomerata L. as indicator of chemical pollution in coastal areas of Farahabad Region, Iran. Revista Publicando 14(2): 183-191.
3. Ebadi AG, Hisoriev H (2018) Physicochemical characterization of sediments from Tajan River Basin in the Northern Iran. Toxicological & Environmental Chemistry 100(5-7): 540-549.
4. Ebadi AG, Hisoriev H (2018) Metal pollution status of Tajan River – Northern Iran. Toxicological & Environmental Chemistry 99(9-10): 1358-1367.
5. Ebadi AG, Hisoriev H, Aliev K (2017) Measurement of some chemical and biochemical parameters in *Cladophora glomerata L.* from Farahabad Region of Iran. Bulgarian Chemical Communication 49(2): 540-544.
6. Zare S, Ebadi AG, Babaee M (2005) Measurement and survey of organochlorine pesticides (OCPs) level in milk samples of agricultural workers (Mazandaran–Iran). International Journal of Biology and Biotechnology 2(4): 967-970.
7. Sharma S (2023) Precision agriculture: Reviewing the advancements, technologies, and applications in precision agriculture for improved crop productivity and resource management. Reviews in Food and Agriculture 4(2): 45-49.
8. Ninomiya S (2022) High-throughput field crop phenotyping: Current status and challenges. Breeding Science 72(1): 3-18.
9. Xu J, Gu B, Tian G (2022) Review of agricultural IoT technology. Artificial Intelligence in Agriculture 6: 10-22.
10. Satyanarayana S (2024) Increasing the beta-carotene content of rice, maize, and potatoes through genetic modification. International Journal of High School Research 6(1): 1-7.
11. Cheng X, Li H, Tang Q, Zhang H, Liu T, et al. (2024) Trends in the global commercialization of genetically modified crops in 2023. Journal of Integrative Agriculture 23(12): 3943-3952.
12. Gaobotse G, Venkataraman S, Mmereke KM, Moustafa K, Hefferon K, et al. (2022) Recent progress on vaccines produced in transgenic plants. Vaccines 10(11): 1861.
13. EFSA Panel on Genetically Modified Organisms (GMO), Mullins E, Bresson JL, Dalmay T, Dewhurst IC, et al. (2022) Scientific opinion on development needs for the allergenicity and protein safety assessment of food and feed products derived from biotechnology. EFSA Journal 20(1): e07044.
14. Wang XY, Du QJ, Zhang WL, Xu DH, Zhang X, et al. (2022) Enhanced transgene expression by optimization of poly A in transfected CHO cells. Frontiers in Bioengineering and Biotechnology 10: 722722.
15. Ghimire BK, Yu CY, Kim WR, Moon HS, Lee J, et al. (2023) Assessment of benefits and risk of genetically modified plants and products: Current controversies and perspective. Sustainability 15(2): 1722.
16. Sendhil R, Nyika J, Yadav S, Mackolil J, Workie E, et al. (2022) Genetically modified foods: Bibliometric analysis on consumer perception and preference. GM Crops & Food 13(1): 65-85.

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