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Applications of artificial intelligence, machine learning, and deep learning in plant breeding

Eftekhari M.[1]*, Ma C.[2, 3]**, Orlov Y.L.[4, 5]***

[1] *Department of Horticultural Sciences, Faculty of Agriculture, Tarbiat Modares University, Tehran, Iran*
[2] *State Key Laboratory of Crop Stress Resistance and High-Efficiency Production, Center of Bioinformatics, College of Life Sciences, Northwest A&F University, Shaanxi, China*
[3] *Key Laboratory of Biology and Genetics Improvement of Maize in Arid Area of Northwest Region, Ministry of Agriculture, Northwest A&F University, Shaanxi, China*
[4] *Institute of Cytology and Genetics, SB RAS, Novosibirsk, Russia*
[5] *Agrarian and Technological Institute, Peoples' Friendship University of Russia, Moscow, Russia*
** m.eftekhari@modares.ac.ir; ** chuangma2006@gmail.com; *** orlov@bionet.nsc.ru*

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Motivation and Aim: In recent years, the field of plant breeding has witnessed a paradigm shift driven by advancements in artificial intelligence (AI) technologies, including machine learning (ML) and deep learning (DL) technologies. These cutting-edge techniques have transformed our understanding of plant biology. From decoding the intricate molecular mechanisms of plant defense to automating disease detection and optimizing nutrient levels, AI is reshaping the landscape of plant breeding. AI-assisted omics techniques offer insights into plant-pathogen interactions and facilitate the identification of stress-responsive genes [1, 2].
Methods and Algorithms: We have organized thematic journal issue at Frontiers in Plant Science – Research Topic "Applications of artificial intelligence, machine learning, and deep learning in plant breeding" [3]. We overview the papers published in this Research Topic on the application of computer techniques in plant science.
Results: We collected research papers on the topic of AI applications in plant biology in areas of sequencing data analysis, image recognition, technology process optimization [3]. Murmu et al. (https://doi.org/10.3389/fpls.2024.1292054) highlighted the potential of AI algorithms, particularly ML and DL, in decoding complex omics data to elucidate the molecular foundations of plant defense. The authors explored AI-assisted omics techniques' applications, challenges, and prospects in enhancing crop protection strategies and ensuring global food security amidst environmental challenges. By integrating AI with omics technologies, researchers can unravel intricate gene regulatory networks and develop targeted interventions for enhancing crop resilience. As we confront the challenges of climate change and emerging diseases, AI-driven approaches offer a robust toolkit for ensuring global food security and sustainability in agriculture. Climate change poses significant threats to agricultural systems, emphasizing the importance of elucidating cold defense mechanisms in crops. Other authors in the Research Topic introduced the Self Organizing Maps (SOM)-based ML method to decipher gene expression patterns in response to different temperature regimes [3]. The YOLO (You Only Look Once) architecture, known for its real-time object detection capabilities, is employed for object detection in plant image analysis [4]. Li et al. (https://doi.org/10.3389/fpls.2023.1289692) showed the efficacy of the CFNet-

VoVGCSP-LSKNet-YOLOv8s model in accurately identifying cotton pests and diseases amidst challenging environmental conditions. The model's superior performance offers a promising solution for real-time monitoring and early intervention in pest and disease outbreaks. This article heralds a new era in cotton plant breeding, wherein cutting-edge AI, ML, and DL techniques converge to address age-old challenges with remarkable precision and efficiency. A novel DL-based architecture, DeepPlantNet, for efficient and accurate prediction and categorization of plant leaf diseases was introduced. Another key phenotypic trait in plants – pubescence, correlates with stress resistance, particularly in wheat. Artemenko et al. [5] proposed an AI-driven approach using CNNs to automate glume pubescence detection, addressing the limitations of traditional methods and enhancing breeding efficiency. Their method offers a reliable and efficient solution for phenotype analysis, empowering breeders with advanced tools for cultivar selection and stress resilience enhancement.

Conclusion: The analysis of molecular mechanisms underlying plant adaptation to environmental changes and stress response is crucial for plant biotechnology. The key approaches include bioinformatics methods, high-throughput sequencing, and post-genome technologies. Genomics and bioinformatics facilitate the modeling of protein–protein and gene regulatory interactions in plant cells, providing a basis for better crop production and sustainability. Overall, AI, ML, and DL techniques offer unique opportunities from deciphering complex omics data to automating phenotypic trait analysis and disease detection to revolutionize breeding practices, develop stress-tolerant and high-yielding crop varieties, and contribute to global food security in the face of escalating environmental challenges [2]. Continued investment in AI applications in plant breeding holds the key to unlocking the full potential of agriculture. We aim to continue a series of Research Topics (special journal issues) on computational plant biology and bioinformatics application [6] at different publishers' platforms.

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