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Utilisation of Artificial Intelligence in Advancing Plant Breeding

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Plant breeding plays a crucial role in ensuring global food security by developing crop varieties with improved yield, quality, and resilience to biotic and abiotic stresses. Conventional breeding methods, although effective, are time-consuming and labor-intensive due to the complexity of plant genomes and genotype × environment interactions. Recent advances in artificial intelligence (AI) and machine learning (ML) have revolutionized plant breeding by enabling data-driven decision-making, high-throughput phenotyping, and accelerated genetic gain. This review explores the utilisation of AI in modern plant breeding, focusing on its applications in genomic selection, phenomics, trait prediction, climate-resilient breeding, and precision hybrid development. The challenges, ethical considerations, and future prospects of AI-enabled breeding systems are also discussed.

Introduction

Plant breeding has evolved from traditional selection-based methods to molecular and genomic approaches aimed at increasing breeding efficiency. With the advent of next-generation sequencing, high-throughput phenotyping, and big data analytics, plant breeders now face the challenge of managing and interpreting vast datasets. Artificial intelligence (AI), encompassing machine learning, deep learning, and data mining techniques, offers powerful tools to analyze complex biological data and uncover hidden patterns that enhance breeding outcomes. The integration of AI into plant breeding has the potential to significantly reduce breeding cycles, improve prediction accuracy, and optimize resource utilization, thereby accelerating the development of superior crop varieties.

Artificial Intelligence and Its Components in Plant Breeding

AI in plant breeding primarily involves:

- **Machine Learning (ML):** Algorithms that learn from data to make predictions (e.g., random forest, support vector machines).
- **Deep Learning (DL):** Neural networks capable of modeling complex nonlinear relationships (e.g., convolutional neural networks).
- **Computer Vision:** Image-based phenotyping and trait detection.
- **Decision Support Systems:** Integrating multi-source data for breeding decisions.

These components collectively enhance the precision and scalability of breeding programs

AI Applicatons in Plant Breeding

Genomic Selection and Marker-Trait Association

Genomic selection (GS) uses genome-wide markers to predict breeding values. AI models improve GS by:

- Capturing complex non-linear interactions between genes
- Improving prediction accuracy over traditional statistical models
- Accelerating selection decisions without extensive phenotyping

Machine learning models such as random forests, gradient boosting, and deep neural networks outperform classical linear models in many breeding scenarios.

High-Throughput Phenotyping and Phenomics

Phenotyping is a major bottleneck in breeding. AI-powered phenomics enables:

- Automated measurement of plant height, biomass, leaf area, and canopy structure
- Disease and stress detection using image recognition
- Large-scale field and greenhouse phenotyping using drones and sensors

Computer vision and deep learning significantly reduce time and human error in phenotypic data collection.

Trait Prediction and Ideotype Design

AI models integrate genotypic, phenotypic, and environmental data to:

- Predict complex quantitative traits such as yield and stress tolerance
- Identify key trait combinations for ideotype breeding
- Simulate breeding outcomes under different environmental scenarios

This allows breeders to design crop varieties tailored to specific agro-ecological zones.

Climate-Resilient and Stress-Tolerant Breeding

AI facilitates breeding for climate resilience by:

- Analyzing multi-environment trial data
- Predicting genotype × environment interactions
- Identifying genotypes with stable performance under heat, drought, or salinity stress

Such predictive capacity is essential for adapting crops to climate change.

Hybrid Breeding and Parental Line Selection

AI algorithms assist in:

- Predicting hybrid performance and heterosis
- Optimizing parental combinations
- Reducing costly and time-intensive field trials

This improves efficiency in hybrid breeding programs for crops such as maize, rice, and sunflower.

Integration of AI with Emerging Breeding Technologies

AI complements other modern breeding tools, including:

- **Genome Editing:** Identifying target genes for CRISPR-Cas interventions
- **Speed Breeding:** Optimizing selection decisions across rapid breeding cycles
- **Digital Twins:** Simulating crop growth and performance under diverse conditions

The synergy between AI and these technologies accelerates genetic gain.

Advantages of AI-Driven Plant Breeding

- Faster breeding cycles and reduced costs
- Improved prediction accuracy for complex traits
- Efficient utilization of large-scale datasets
- Enhanced decision-making under variable environments
- Reduced dependency on extensive field trials

Challenges and Limitations

Despite its promise, AI adoption in plant breeding faces challenges:

- Limited availability of high-quality, standardized datasets
- Requirement for interdisciplinary expertise
- High computational and infrastructural costs
- Risk of algorithm bias and lack of interpretability
- Data ownership and ethical concerns

Addressing these issues is critical for effective implementation.

Future Prospects

Future advancements are expected in:

- Explainable AI models for transparent breeding decisions
- Integration of multi-omics data (genomics, transcriptomics, metabolomics)
- Real-time decision support systems for breeders

- Democratization of AI tools for small-scale breeding programs

AI-driven plant breeding will play a pivotal role in meeting future food security challenges.

Conclusion

Artificial intelligence is transforming plant breeding by enabling predictive, precise, and accelerated crop improvement. Through enhanced genomic selection, automated phenotyping, and climate-adaptive breeding strategies, AI significantly improves breeding efficiency and genetic gain. Continued interdisciplinary collaboration and responsible deployment will ensure that AI becomes an integral component of sustainable plant breeding systems.

References

1. Crossa, J., et al. (2017). Genomic selection in plant breeding: Methods, models, and perspectives. *Trends in Plant Science*, 22(11), 961–975.
2. Montesinos-López, O.A., et al. (2018). Deep learning in plant breeding. *G3: Genes, Genomes, Genetics*, 8, 3637–3648.
3. Yang, W., et al. (2020). Crop phenomics and high-throughput phenotyping: Past, present, and future. *Plant Phenomics*, 2020, 1–15.