
POPULAR ARTICLE

Artificial intelligence and its role in plant breeding

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Importance of artificial intelligence (AI)

Artificial intelligence (AI) is the technology that enables machines to simulate human cognitive functions, such as learning, reasoning, problem-solving, and decision-making, to perform tasks that traditionally require human intelligence. By analyzing vast amounts of data, AI systems can learn from experience, recognize patterns, understand language, make predictions, and even generate creative content. Applications of AI are diverse, ranging from voice assistants and search engines to medical diagnosis, autonomous vehicles, and customer support systems.

AI relies on specialized hardware and software, including machine learning algorithms, to process data and learn from it. Key components include:

- **Data assimilation:** AI systems consume large datasets to identify patterns and trends.

- **Machine learning:** A core AI subfield that allows systems to learn and adapt from new information without being explicitly programmed.
- **Algorithmic processing:** Sophisticated algorithms process the data to enable tasks like pattern recognition, problem-solving, and language understanding.

Artificial intelligence and plant breeding

Harnessing cutting-edge technologies to enhance crop productivity is a pivotal goal in modern plant breeding. Artificial intelligence (AI) is renowned for its prowess in big data analysis and pattern recognition, and is revolutionizing numerous scientific domains including plant breeding. We explore the wider potential of AI tools in various facets of breeding, including data collection, unlocking genetic diversity within genebanks, and bridging the genotype-phenotype gap to facilitate crop breeding. This will enable the development of crop cultivars tailored to the projected future environments.

Moreover, AI tools also hold promise for refining crop traits by improving the precision of gene-editing systems and predicting the potential effects of gene variants on plant phenotypes. Leveraging AI-enabled precision breeding can augment the efficiency of breeding programs and holds promise for optimizing cropping systems at the grassroots level. This entails identifying optimal intercropping and crop-rotation models to enhance agricultural sustainability and productivity in the field. AI is accelerating and enhancing plant breeding by using machine learning and other techniques to analyze vast genomic, phenotypic (plant traits), and environmental data. This enables breeders to predict crop yields, identify desirable traits like disease resistance, optimize breeding programs, and

Key applications of AI in plant breeding

- **Predictive breeding:**

AI algorithms analyze genomic and environmental data to predict how different plant genotypes will perform under various conditions, helping breeders select for desirable traits.

- **High-throughput phenotyping:**

AI automates the measurement and analysis of plant characteristics from large datasets collected via remote sensing, imaging, and other high-throughput methods, overcoming traditional bottlenecks.

- **Yield prediction:**

Machine learning models use historical data, weather conditions, and other variables to predict crop yields, aiding breeders in making informed decisions.

- **Disease and pest detection:**

AI-powered image recognition and sensor data analysis can detect diseases and pests early, enabling timely intervention and contributing to resistance breeding.

- **Trait selection and optimization:**

AI identifies complex relationships between genetic factors and phenotypic traits,

develop climate-resilient crops more efficiently and precisely than traditional methods. AI also improves high-throughput phenotyping by automating data collection and analysis, leading to faster development of improved crop varieties for increased food security and sustainability. 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.

improving the precision and efficiency of selecting plants with desired characteristics.

- **Gene editing refinement:**

AI tools can help improve the precision of gene-editing systems like CRISPR, predicting the potential effects of gene variants on plant phenotypes.

- **Climate adaptation:**

AI assists in developing crops that are more resilient to changing climate conditions by predicting how different genotypes will perform under various environmental scenarios.

How AI achieves these applications.

- **Data integration:**

AI integrates diverse datasets, including genomics, phenomics (plant traits), and enviromics (environmental factors), to uncover hidden patterns and relationships.

- **Advanced algorithms:**

Machine learning and deep learning algorithms are used to process complex, multi-dimensional datasets, identify correlations, and build predictive models.

- **Automation:**
AI automates data analysis, from image recognition for plant identification to processing large-scale genomic data, reducing manual effort and speeding up the breeding cycle.
Challenges and the Future:
- **Data biases:**
Ensuring that AI models are robust and free from biases is an on-going area of research.
- **Interpretability:**
Making AI models more interpretable is crucial for understanding the underlying biological mechanisms driving plant traits.
- **Collaboration:**
Interdisciplinary collaboration between AI researchers, plant breeders, and other stakeholders is essential to fully realize AI's potential in creating a food-secure future.

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