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DE-NOVO DOMESTICATION OF WILD PLANTS: A NEW FRONTIER IN CROP IMPROVEMENT

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Domestication of plants is one of the most significant milestones in human civilization. Over thousands of years, early farmers selected wild plants with desirable traits such as larger seeds, non-shattering spikes, reduced dormancy, and improved taste, gradually transforming them into modern crops. While this traditional domestication process laid the foundation of global agriculture, it was slow, imprecise, and often accompanied by the loss of valuable traits such as stress tolerance and disease resistance.

In the present era, agriculture faces unprecedented challenges including climate change, increasing population pressure, shrinking arable land, and the emergence of new pests and diseases. Many modern crops possess a narrow genetic base due to repeated selection and breeding, making them vulnerable to environmental stresses. In contrast, wild plant species harbor rich genetic diversity and inherent resilience to adverse conditions. However, their poor agronomic traits limit direct cultivation.

Recent advances in plant biotechnology, especially genome editing technologies like CRISPR/Cas systems, have enabled a revolutionary approach known as de-novo domestication. This strategy aims to rapidly domesticate wild plants by precisely editing key domestication-related genes, thereby combining the resilience of wild species with the productivity and uniformity required for agriculture. De-novo domestication represents a promising pathway for developing climate-resilient and sustainable crops for the future.

Concept of De-novo Domestication

De-novo domestication refers to the rapid and targeted domestication of wild plant species using modern genome editing and molecular breeding tools. Unlike conventional breeding, which relies on crossing wild relatives with cultivated varieties over many generations, de-novo domestication directly modifies specific genes responsible for domestication traits while retaining the beneficial stress-adaptive characteristics of wild plants.

The concept is based on the understanding that many domestication traits—such as seed size, plant architecture, flowering time, fruit shape, and loss of seed shattering—are controlled by a relatively small number of genes. With the availability of whole-genome sequences and functional genomics data, these key genes can be identified in wild species. Genome editing tools, particularly CRISPR/Cas9, base editing, and prime editing, are then used to alter these genes in a precise manner.

For example, genes controlling seed shattering, apical dominance, or fruit size can be edited to mimic domesticated forms, while genes responsible for abiotic stress tolerance, pest resistance, and nutrient efficiency are preserved. Importantly, de-novo domestication can be achieved without introducing foreign DNA, resulting in genome-edited plants that are often indistinguishable from naturally mutated varieties.

Thus, de-novo domestication represents a shift from the traditional "domestication first, improvement later" model to a modern approach of "retain wild strength, add domestication traits."

Discussion

Advantages of De-novo Domestication

One of the major advantages of de-novo domestication is the speed of crop development. Traditional domestication and breeding may take decades, whereas genome editing can achieve similar outcomes within a few generations. This is particularly important in the context of rapidly changing climates and emerging agricultural challenges.

Another key benefit is the retention of genetic diversity. Modern crops often suffer from genetic bottlenecks, but de-novo domestication allows direct utilization of wild species with broad genetic variation. This can result in crops with enhanced tolerance to drought, salinity, heat, flooding, and poor soils.

De-novo domestication also expands the crop portfolio. Many wild species that were previously neglected or underutilized can be transformed into new crops. These "neo-crops" may be better adapted to marginal environments and can contribute to food and nutritional security.

Examples and Case Studies

Several successful examples demonstrate the potential of de-novo domestication. In wild tomato (Solanum pimpinellifolium), researchers have edited genes related to fruit size, shape, and plant architecture, creating lines with improved yield while retaining stress tolerance. Similarly, wild rice species have been targeted to modify traits like seed shattering and flowering time, opening possibilities for developing climate-resilient rice varieties.

In orphan crops and wild relatives of cereals, legumes, and oilseeds, de-novo domestication is being explored to address region-specific agricultural needs. This approach is particularly relevant for regions like the North Eastern and rainfed areas of India, where wild and semi-domesticated species are abundant but underutilized.

Challenges and Limitations

Despite its promise, de-novo domestication faces several challenges. A major limitation is the lack of genomic and functional information for many wild species. Without high-quality genome sequences and gene annotations, identifying domestication-related genes becomes difficult.

Another challenge is transformation and regeneration efficiency. Many wild species are recalcitrant to tissue culture and genetic transformation, which can limit the application of genome editing.

Regulatory and public acceptance issues also play a crucial role. Although genome-edited crops without foreign DNA are increasingly treated differently from transgenic GM crops, regulatory frameworks vary across countries. Clear guidelines and public awareness are essential for the successful deployment of de-novo domesticated crops.

Future Prospects

The integration of de-novo domestication with other emerging technologies such as speed breeding, artificial intelligence, genomic selection, and microbiome engineering will further enhance its impact. As sequencing costs decline and editing tools become more efficient, de-novo domestication is expected to become a mainstream strategy in crop improvement programs, especially in public-sector research.

Conclusion

De-novo domestication of wild plants represents a paradigm shift in plant biotechnology and crop improvement. By combining the resilience and genetic diversity of wild species with the precision of genome editing, this approach offers a powerful solution to the limitations of conventional breeding and traditional domestication.

In the face of climate change, food insecurity, and sustainability concerns, de-novo domestication provides an opportunity to develop novel, climate-resilient crops tailored to diverse agro-ecological conditions. Although challenges related to genomics, transformation, regulation, and public perception remain, continued research and supportive policies can unlock the full potential of this innovative strategy.

Overall, de-novo domestication is not merely a technological advancement but a strategic tool for ensuring future food and nutritional security while conserving valuable plant genetic resources.

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