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De Novo Domestication of Wild Species Using Genome Editing Tools

*Kishori Anna Wagh¹, M. R. Prajapati², V P Patel², P. N. Parmar² and M. N. Chaudhary²

¹Department of Genetics and Plant Breeding, Mahatma Phule Krishi Vidyapeeth, Rahuri, Maharashtra, India

²Regional Rice Research Station, Navsari Agricultural University, Gujarat, India

*Corresponding Author's email: kishoriwagh444@gmail.com

De novo domestication is an emerging strategy in plant breeding that aims to rapidly transform wild plant species into new crops using modern genome editing technologies. Traditional domestication has taken thousands of years to convert wild plants into cultivated forms through selection for traits such as larger fruits, reduced seed shattering and improved yield. However, many wild relatives of crops possess valuable traits such as stress tolerance, disease resistance and adaptability to harsh environments. Genome editing tools such as CRISPR/Cas systems now enable precise modification of domestication related genes in wild species while retaining their natural resilience. This approach accelerates crop development and expands agricultural biodiversity. De novo domestication offers promising opportunities for creating climate resilient crops and improving food security under changing environmental conditions. This article highlights the concept, mechanisms, applications and future prospects of de novo domestication using genome editing tools.

Keywords: De novo domestication, genome editing, CRISPR/Cas, wild species, crop improvement, precision breeding

Introduction

Crop domestication is one of the most significant achievements in human history. Over thousands of years humans have selected plants with desirable traits such as higher yield, improved taste, non-shattering seeds and reduced toxicity. This long process resulted in the development of modern crops such as rice wheat maize and tomato. However, domestication also caused genetic bottlenecks which reduced diversity and limited the ability of crops to adapt to environmental stresses. Wild plant species and crop wild relatives contain a rich reservoir of genetic variation including resistance to pests, tolerance to drought and salinity and adaptation to marginal soils. Harnessing these traits is essential for sustainable agriculture. De novo domestication is a new concept that combines the resilience of wild species with the productivity of cultivated crops by using genome editing tools. This approach enables rapid domestication within a few generations and provides new opportunities for crop diversification.

Concept of De Novo Domestication

De novo domestication refers to the process of directly domesticating wild species by editing key domestication genes rather than relying on long term selection. Genome editing allows precise modifications in genes controlling domestication traits such as plant architecture, fruit size, flowering time and seed dispersal.

Unlike conventional breeding which introduces wild traits into elite cultivars through repeated backcrossing de novo domestication develops entirely new crops from wild species while maintaining their stress tolerance and ecological adaptability.

Genome Editing Tools Enabling De Novo Domestication

The success of de novo domestication is largely driven by advances in genome editing technologies. CRISPR/Cas systems have become the most widely used tools due to their simplicity efficiency and precision. Genome editing enables targeted mutations in domestication genes through mechanisms such as non-homologous end joining and homology directed repair. Recent improvements including base editing and prime editing allow even more precise nucleotide level modifications. These technologies make it possible to rapidly modify multiple genes simultaneously which is essential for domestication of complex traits.

Key Domestication Traits Targeted in Wild Species

De novo domestication focuses on editing genes associated with classical domestication syndrome traits. Important targets include seed shattering genes to prevent yield loss and plant architecture genes to improve harvestability. Fruit size and shape genes are also edited in wild fruits to increase consumer acceptability. Flowering time regulators are modified to ensure synchronization with agricultural seasons. Reduction of bitter or toxic compounds is another major objective when domesticating wild edible plants.

Successful Examples of De Novo Domestication

Several proof-of-concept studies have demonstrated the potential of de novo domestication. Wild tomato species have been edited for increased fruit size, improved yield and compact growth habit while retaining stress tolerance. Similarly, genome editing in wild rice relatives has targeted genes controlling grain size and shattering traits. Efforts are also underway in orphan crops and underutilized species to develop new climate resilient crops for future agriculture. These examples highlight the feasibility of rapid domestication through genome editing.

Advantages of De Novo Domestication Approach

De novo domestication provides multiple advantages over conventional breeding. It significantly reduces the time required to develop new crops compared to traditional domestication. It enables the direct use of wild genetic diversity without losing valuable stress tolerance traits. This approach also expands crop biodiversity by introducing new species into cultivation which can enhance resilience of agricultural systems. De novo domestication supports sustainable agriculture by reducing dependency on chemical inputs and improving adaptation to climate change.

Challenges and Limitations

Despite its promise de novo domestication faces several challenges. Limited genomic information and transformation protocols for many wild species restrict its application. Complex domestication traits are often controlled by multiple genes and their editing requires careful optimization. Regulatory frameworks for genome edited crops differ across countries which may influence adoption. Ethical and socio-economic considerations regarding new crops and biodiversity conservation must also be addressed.

Future Prospects and Research Directions

The future of de novo domestication lies in integrating genome editing with genomics transcriptomics proteomics and phenomics. Multi omics approaches will help identify key domestication genes and regulatory networks. Advances in artificial intelligence and machine learning will support prediction of domestication targets and accelerate breeding decisions. De novo domestication of stress tolerant wild species can contribute significantly to climate smart agriculture and global food security. Expanding research on orphan crops and wild edible plants will open new opportunities for sustainable crop development.

Conclusion

De novo domestication using genome editing tools represents a revolutionary approach in modern plant breeding. By precisely editing domestication related genes in wild species it is possible to rapidly develop new crops that combine high productivity with natural stress tolerance. This strategy has the potential to expand agricultural biodiversity and create climate resilient crops suited for future challenges. Continued advancements in genome editing technologies and supportive regulatory frameworks will be essential to fully realize the benefits of de novo domestication for sustainable agriculture.

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