



POPULAR ARTICLE

From wild plants to future crops: The rise of *de novo* domestication

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Intricacies of the subject

Crop domestication is one of the most important achievements in human history. Through generations of selection, wild plants were transformed into productive crops with larger seeds, improved plant architecture, synchronized maturity, reduced seed shattering and other traits that made cultivation and harvesting easier. However, this long process also narrowed the genetic diversity available in many modern crops. Valuable alleles for drought tolerance, heat tolerance, disease resistance, salinity tolerance and adaptation to marginal environments may remain in wild relatives or underutilized species. *De novo* domestication represents a new approach to this problem. Instead of transferring individual useful traits from a wild relative into an established crop, researchers attempt to convert the wild species itself into a useful crop. By combining genome sequencing, comparative genomics, gene discovery and

precise genome editing, undesirable domestication-related traits can potentially be modified while valuable natural adaptations are retained. This approach is gaining attention as agriculture faces climate change, soil degradation, water scarcity and the need to produce nutritious food with fewer inputs. Wild and underutilized plant species offer a valuable reservoir of genetic diversity and adaptive traits that can help develop resilient, nutritious and resource-efficient crops. The central idea is simple: rather than asking only how existing crops can be improved, scientists can also ask which wild plants have the potential to become the crops of the future.

From ancient domestication to *de novo* domestication

Traditional domestication occurred gradually. Early farmers selected plants with characteristics that were convenient or beneficial for cultivation and consumption.



produced the major crops known today. During this process, however, domesticated crops experienced genetic bottlenecks. Some variation present in wild populations was lost as breeding became concentrated around a limited number of preferred types. Modern breeding can recover useful variation through crossing with wild relatives, but this process is often complicated. A wild donor may carry both desirable and undesirable characteristics, and several generations of backcrossing and selection may be required. *De novo* domestication takes a different route: retain the wild genetic background and modify selected traits that make the plant difficult to cultivate. The approach therefore combines the strengths of wild plants and modern biotechnology. Wild species provide naturally evolved adaptation, while genomics and genome editing provide the precision needed to improve agronomic performance.

What Is *De Novo* domestication?

De novo domestication can be defined as the rapid conversion of a wild or semi-wild plant into an agriculturally useful crop by modifying key domestication-related traits while retaining valuable characteristics already present in the wild plant. A typical *de novo* domestication programme can be organized into the following stages:

- Selection of a promising wild or underutilized species with valuable characteristics such as drought tolerance, heat tolerance, disease resistance, nutritional quality or adaptation to marginal environments.
- Genome characterization using whole-genome sequencing, comparative genomics, transcriptomics and, increasingly, pangenomic approaches.
- Identification of genes and regulatory regions associated with traits such as plant architecture, flowering, fruit or seed size,

seed shattering, branching, maturity and yield components.

- Targeted genome editing of selected genes or regulatory regions using CRISPR-based technologies.
- Generation advancement, phenotyping and selection under relevant field environments.
- Multi-environment evaluation to determine productivity, stability, ecological safety and suitability for farmers.

Why wild plants matter?

Wild plants are often overlooked because they may have small fruits or seeds, sprawling growth, asynchronous flowering, strong seed shattering or other characteristics that make them difficult to manage. Yet these same plants may possess valuable adaptations that have evolved under natural selection. A wild species growing naturally in a drought-prone environment may contain mechanisms that allow it to maintain growth under water limitation. A plant from saline habitats may possess mechanisms for salt tolerance, while another wild relative may carry resistance to pathogens or insects. These characteristics can be particularly valuable when conventional elite varieties perform poorly under environmental stress. *De novo* domestication seeks to preserve this natural resilience rather than replacing the entire genetic background through repeated crossing. The objective is to make the plant more productive and manageable without losing the biological advantages that allowed it to survive in challenging environments

CRISPR: The accelerator behind *de novo* domestication

The development of CRISPR-based genome editing has greatly expanded the possibilities for *de novo* domestication. CRISPR systems can be directed toward specific genomic



sequences, allowing researchers to modify genes or regulatory regions associated with important traits. Many domestication traits have a relatively clear genetic basis. Plant architecture, flowering time, fruit and seed characteristics, shattering and other traits have been studied extensively in major crops. Once corresponding genes are identified in a wild species, they can become potential targets for genome editing. Modern editing platforms are also becoming increasingly versatile. In addition to conventional gene disruption, newer approaches can make more precise sequence changes or alter gene regulation. This provides breeders with a growing toolkit for developing crop ideotypes suited to specific environments.

Groundcherry: A landmark example

Groundcherry (*Physalis pruinosa*) is an important example of the concept. Although it produces attractive edible fruit and has potential as an alternative crop, its plant architecture and fruiting characteristics are less suited to intensive agriculture than those of established crops. Researchers used knowledge from domesticated tomato and related species to identify genes associated with important domestication traits in groundcherry. Genome editing was then used to modify selected targets affecting plant architecture including flowering and fruit characteristics. The study demonstrated that a relatively small number of targeted genetic changes can produce substantial improvements in agronomic traits. This example provided an important proof of concept: a species does not necessarily need centuries of conventional selection before it can acquire useful crop characteristics.

Wild tomato and the expansion of the concept

Wild tomato relatives have also demonstrated the potential of *de novo* domestication. *Solanum pimpinellifolium* contains useful genetic diversity but produces much smaller fruits than modern cultivated tomato. Researchers have used genome editing to modify multiple domestication and improvement genes, producing changes in fruit size, fruit number and other characteristics. These experiments illustrate an important principle: knowledge accumulated through the domestication of major crops can serve as a genetic toolkit for improving related wild species. As more crop genomes and pangenomes become available, this knowledge can increasingly be applied beyond traditional model crops.

De Novo domestication for climate-resilient agriculture

Climate change is creating combinations of stresses that challenge conventional agriculture. Higher temperatures, irregular rainfall, drought, salinity, emerging pests and diseases can occur together, making resilience increasingly important. Wild plants represent a large reservoir of adaptations to these environments. *De novo* domestication offers a strategy for combining such adaptations with agricultural traits. A drought-adapted wild species, for example, could potentially be improved for plant architecture, harvestability and yield without eliminating its underlying drought resilience. This concept could also contribute to diversification of agriculture. Instead of relying almost entirely on a small number of globally dominant crops, future farming systems could include a broader range of locally adapted species.

Potential applications

De novo domestication has several potential applications in developing crops suited to



challenging agricultural environments. In improved drought tolerance, stable reproduction, and efficient water use. In saline soils, it may support the development of crops with enhanced salt tolerance and improved ion regulation. For hot environments, *de novo* domestication could help produce crops with greater heat resilience and stable flowering under high temperatures. In low-input farming systems, it may contribute to crops with improved nutrient-use efficiency and strong adaptation to environmental stresses. In disease-prone regions, wild plants with natural disease resistance can be domesticated to develop more resilient crops. For marginal lands, the approach could help develop crops adapted to poor or stressful soils. In urban and protected cultivation, compact plant architecture could make crops easier to grow in limited spaces. Finally, for sustainable production, *De novo* domestication could contribute to crops that require fewer external inputs such as fertilizers, irrigation, and crop-protection products.

Challenges and limitations

Despite its promise, *de novo* domestication is not a universal solution. Many complex traits, including drought tolerance, yield stability and nutrient-use efficiency, are controlled by numerous genes and are strongly influenced by the environment. Editing one gene may also affect multiple biological processes. Pleiotropy, gene interactions and gene–environment interactions therefore need to be carefully evaluated. Transformation and regeneration can be major technical barriers, particularly in wild or underutilized species for which reliable tissue-culture protocols are unavailable. Field performance is another major consideration. A promising edited plant must demonstrate stable performance across environments rather than only under controlled conditions. Seed production, agronomic

drought-prone regions, it can help crops with practices, consumer acceptance, regulatory requirements and farmer adoption must also be considered. Ecological assessment is equally important. A stress-resilient wild plant converted into a crop should be evaluated for potential weediness, gene flow and interactions with surrounding ecosystems. Conservation of the original wild genetic resources should remain a priority.

A new role for plant breeders

De novo domestication does not make conventional breeding obsolete. Instead, it creates a more integrated breeding framework in which field evaluation, germplasm conservation, genomics, genome editing, speed breeding and quantitative genetics work together. A future breeding programme may begin with the identification of wild plants adapted to a target environment, followed by genomic characterization and phenotyping. Candidate domestication genes can then be identified, edited and evaluated through rapid generation advancement. The resulting material must still undergo rigorous field testing and farmer-oriented selection. In this framework, plant breeders are not only selecting useful variation that already exists. They are also using genetic information to design new combinations of traits.

From crop improvement to crop creation

Traditional breeding generally starts with an established crop and seeks to make it better. *De novo* domestication begins with another question: which wild or underutilized plants have the potential to become crops? This change in perspective could expand the crop portfolio. Plants currently regarded as wild relatives, orphan crops or underutilized species may contain nutritional, ecological or stress-adaptation advantages that have received little



change in perspective could expand the crop portfolio. Plants currently regarded as wild relatives, orphan crops or underutilized species may contain nutritional, ecological or stress-adaptation advantages that have received little breeding attention. With continuing advances in genome sequencing, artificial intelligence-assisted gene discovery, high-throughput phenotyping, genome editing and speed breeding, the distinction between a wild plant and a crop may become increasingly flexible.

The road ahead

The future of agriculture may depend not only on improving the crops that are already widely cultivated but also on discovering new crops hidden within existing biodiversity. Wild plants represent millions of years of evolutionary experimentation and contain adaptations that could become valuable under future climates. *De novo* domestication provides a framework for combining these natural adaptations with carefully selected agronomic traits. Its greatest value may therefore be its ability to broaden the genetic and biological foundation of agriculture. The crops of the future may not all have histories extending thousands of years. Some could be relatively young crops developed from wild plants, guided by genomics and genome editing, and selected specifically for the environmental and nutritional demands of tomorrow.

Conclusion

De novo domestication represents a shift from simply improving existing crops to exploring the possibility of creating new ones. By combining the natural resilience of wild plants with genomic technologies and precise genome editing, researchers can potentially

develop crops better suited to climate change, marginal environments and sustainable production. The approach is still developing and faces biological, technical, ecological and regulatory challenges, but its central idea is powerful: the genetic diversity needed for future agriculture may already exist in nature. The challenge is to understand it, preserve it and use it responsibly.

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