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Popular Article

***De Novo* Domestication: An Accelerated Plant Breeding Approach Towards New Crop For Food Security**

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Abstract

De novo domestication is a novel approach to crop breeding that involves introducing domestication genes into semi-domesticated and non-domesticated plants. This method preserves the intrinsic favourable phenotypes of crop wild relatives or semi-wild plants, such as their resistance to biotic and abiotic stresses, while enabling them to gain desirable domestication features. While the conventional approach to domesticating wild plants remains a viable means of producing new crops, the latest advancements in CRISPR-Cas technology allow for the quick *de novo* domestication of wild plants. The *de novo* domestication strategy, its prerequisites, and its impact on the development of orphan crops, perennials, and polyploids are covered in this section.

Introduction

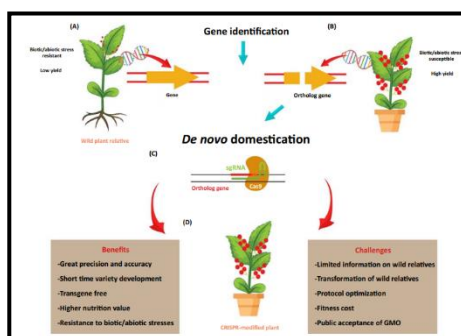
Major crops were first domesticated about 12,000 years ago. Over 2500 plant species are thought to have been domesticated or semi-domesticated for food. Three primary crops—rice, wheat, and maize—provide 60% of the calories consumed by humans today, although only 20 plant species account for 90% of the world's calories. Other minor or orphan crops that have the potential to address food security challenges have lost ground to the big three as a result of the attention paid to them, both commercially and agriculturally. Therefore, *de novo* domestication of wild or semi-wild plants through genetic manipulation of the homologous domestication genes represents a second route for future crop design, in addition to the sluggish development of currently well-cultivated crops through conventional breeding. *De novo* domestication, which involves introducing domestication genes into non-domesticated and semi-domesticated plants, is a novel breeding technique for new crop species.

Pre-requisites of *de novo* domestication

- Prior knowledge of domestication traits and gene loci



- Genome sequencing of the target minor or wild crop
- Orthologous genes for *de novo* crop domestication
- Reference genome sequence of related species
- Efficient transformation protocol



(Source: Khan *et al.*, 2019)

Fig. 1. Schematic representation of *de novo* domestication and its challenges and benefits
***De novo* domestication and crop improvement**

***De novo* domestication of orphan crops**

Wild plants that are not well-known to the general public and have not undergone extensive artificial selection are known as orphan crops. Local populations have been using orphan crops for millennia due to their superior nutritional qualities and environmental adaptability. However, because to their lower production, narrower range, and modest resistance to pests and diseases, they are unable to compete with important crops. Although it can be difficult to improve the quality of orphan crops through conventional breeding, guided nuclease genetic alteration provides an excellent platform. Recently, *de novo* domestication using genome editing has been shown for the orphan Solanaceae crop *Physalis pruinosa*, sometimes known as "groundcherry" (Lemmon *et al.*, 2018). They altered tomato domestication and improvement orthologues that regulate fruit size, flowering time, and plant architecture, thereby improved these major productivity traits.

***De novo* domestication of perennials**

A perennial grain crop, which does not need to be grown every year, would produce a long-lived deep root system capable of sequestering carbon while efficiently absorbing nutrients and water. Perennial legumes and this crop could be interplanted to provide extra ecosystem services like nitrogen fixing. Moreover, in a perennial grain domestication programme, the extensive root systems, vast storage reserves, and stress tolerance of perpetual forebears would offer plenty of mechanisms for creating new crops adaptable to a broad range of challenges. More species with desired features are being bred with the purpose of adding them to the list of domesticated plants. Numerous underutilized, nitrogen-fixing legumes may be grown as crops on low-input, low-nutrient soils, and frequently have high nutritive value. Perennial plants generally

have more developed root systems than modern annual crops, which helps to maintain soil quality while also enabling them to be less reliant on water and fertiliser. Therefore, efforts to domesticate perennials and turn annuals into perennials are currently underway in the breeding process.

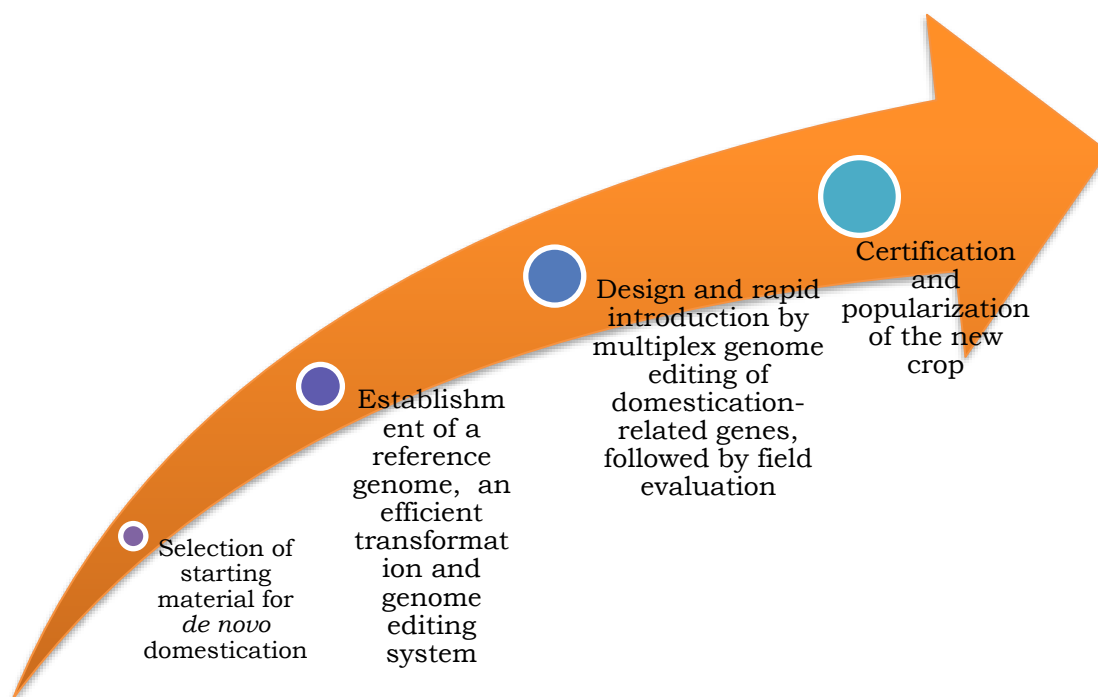


Fig. 2. Road map of *de novo* domestication

***De novo* domestication of polyploids**

In flowering plants, polyploidy is a prevalent method of evolution that arises largely via whole genome duplications or interspecific hybridizations. Polyploid plants offer substantial advantages in biomass, vigorousness, and powerful response to environmental changes. More advantageous genetic variations, such as disease resistance, environmental adaptability, and enhanced local environment adaptation, can be found in polyploids. When it comes to certain features, such as bigger seeds or grains, some polyploids display "gigantism." It is well known that polyploid plants offer advantages in terms of growth vigour and environmental adaptation. Consequently, crop polyploidization might be crucial to the development of next-generation crops that are meant to address issues related to food security.

A *de novo* domestication method for *Oryza alta*, an allotetraploid rice, has been published recently (Yu *et al.*, 2021). It is the first instance of a polyploid plant and wild cereal being domesticated from scratch. In order to produce the desired features, the authors of this study used CRISPR-Cas9 tools to delete homologs of the genes regulating heading dates, plant height, awn length, grain size, and seed shattering from the *O. alta* genome. Finally, by combining the benefits of polyploidy, functional genomics knowledge of cultivated crops, desirable attributes of wild species, and rapid genetic modification(s) through genome editing *de novo* domestication of *O.*



alta, a wild allotetraploid rice, the strategy shows a clear path for creating novel crops in the future.

Conclusion

De novo domestication, as demonstrated by recent works, represents a paradigm shift in utilising the natural genetic diversity of plants by introducing traits related to domestication and improvement into wild plants with unique traits through genome editing, even though there is still much work to be done. This is in contrast to the prevailing strategy, which makes use of natural genetic variety to introduce desirable traits—like high grain nutritional content and favoured architectural features—into already-existing crops via genome editing or hybridization. Recent developments in CRISPR-Cas technologies in plants, such as base editing, prime editing, and gene targeting, along with novel genetic transformation methods, are expected to trigger an exciting wave of *de novo* domestication of wild plants to produce products that are suited to specific needs.

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