ANNALS OF THE UNIVERSITY OF CRAIOVA

Series: ✓ *Biology*
✓ *Horticulture*
✓ *Food products processing technology*
✓ *Environmental engineering*

Vol. XXX (LXVI) - 2025

GENETIC DIVERSITY AND ADAPTABILITY IN PRUNUS SPECIES – PERSPECTIVES FOR CONSERVATION AND BREEDING

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Keywords*: diversity, adaptability, resilience, breeding, species*

ABSTRACT

The genus Prunus comprises a wide range of species, characterized by genetic variability in all its cultivated forms. This diversity is reflected in the species' adaptability to varied soil and climatic conditions, tolerance to biotic and abiotic stress, and their ability to ensure production stability in the context of climate change. Global studies highlight species such as Prunus cerasifera for their remarkable ecological plasticity, providing valuable genetic resources for breeding programs. At the same time, modern agriculture pressures, such as variety standardization and the loss of local cultivars, lead to reduced biodiversity, underlining the need for germplasm conservation. Gene banks and genetically assisted selection strategies represent viable solutions for preserving and sustainably using genetic resources. Moreover, phenological, physiological, and genetic analyses of these species significantly contribute to understanding adaptation mechanisms, offering solid foundations for the development of sustainable and resilient agriculture.

INTRODUCTION

The genus *Prunus* exhibits high variability, demonstrated both in well-known species and in those less studied but of particular practical importance in pomology. These species stand out for their remarkable ability to adapt to different environmental conditions, tolerating both low and high temperatures, as well as soils with varied textures and compositions. This ecological plasticity enables the expansion of cultivation in diverse regions, contributing to production stability and global food security. In a context of climate change and soil degradation, the cultivation of *Prunus* species becomes a viable solution for maintaining agricultural yields and developing sustainable horticultural practices (Khadivi et al., 2022). As perennial organisms, *Prunus* species are constantly exposed to abiotic and biotic stress factors, forcing them to develop response and adaptation mechanisms (Conrad et al., 2019). Phenology is the main trait affected by climate change, being considered one of the most sensitive characteristics (Cosmulescu et al., 2010, 2021; Cosmulescu & Călușaru, 2020). In addition, climate change impacts physiology and species distribution, as well as community composition and dynamics (Dinu et al., 2022; Cosmulescu et al., 2008). Flowering intensity is influenced by minimum spring temperatures, with late frosts having a major impact on reproductive success (Cosmulescu & Gruia, 2016).

Excessive light also affects phenophases and photosynthesis (Korsakova et al., 2023). Agricultural shifts represent another factor directly affecting genetic diversity. The gradual replacement of local cultivars with improved varieties has reduced biodiversity, highlighting the need to conserve traditional genetic resources to support sustainable agriculture (Mirheidari et al., 2020). Domestication has introduced modifications to both economic and agronomic traits while preserving genetic characteristics. The analysis of genetic variation in local and cultivated populations provides valuable insights into domestication mechanisms and forms a solid foundation for breeding programs. Nevertheless, domestication may reduce genetic diversity, making the preservation of local genotypes essential for understanding genomic variation and advancing genetic improvement of *Prunus* species (Li et al., 2020). The aim of this paper is to synthesize the literature on the genetic diversity and adaptability of *Prunus* species, highlighting the implications for genetic resource conservation and future directions in breeding.

MATERIAL AND METHODS

This study is based mainly on literature review, using relevant bibliographic sources such as monographs, scientific articles, and academic databases to access the most up-to-date research findings in the field. The adopted methodology consisted of documentary research, with a focus on the critical analysis of existing literature concerning the genus *Prunus*, with special emphasis on diversity, adaptability, conservation, and breeding methods. The integration and synthesis of the collected information allowed the formulation of coherent, well-supported conclusions regarding the role and importance of genetic diversity in global horticulture.

RESULTS AND DISCUSSIONS

Genetic diversity and adaptability to climate change

Genetic diversity plays a crucial role in maintaining different genes that confer resistance to diseases, pests, and stress conditions. Facing recent climate changes, many species survive in cultivation due to genetic variation, which enables adaptation to different stress factors (Salgotra & Chauhan, 2023). Breeders use genetic diversity to develop new cultivars and improve existing ones, ensuring food security, sustainability, and adaptation to climate change. Recent climate change will have unfavorable consequences for many cultivars. Agricultural regions worldwide are experiencing unusually high or low temperatures, excessive rainfall, or drought, which lower the resilience of fruit trees and other crops. Plant breeding can produce new collections to withstand these adverse conditions (Swarup et al., 2021). Abiotic stress negatively affects plant growth and development, causing significant yield losses. Among abiotic factors impacting fruit production, excess soil salts are considered the most damaging. Soil salinization, mainly caused by natural factors but also by improper irrigation practices or excessive fertilizer use, is a growing threat affecting about 20 % of irrigated lands. *Prunus* species range from moderately sensitive to very sensitive to salinity, reflecting tolerance gradients within the genetic pool of the genus. Higher genetic diversity included in cultivated germplasm is essential for sustained crop improvement, and characterizing this diversity and its interaction with environmental factors is crucial for its appropriate use in breeding programs (Toro et al., 2021). Human domestication of plants, initiated about 10,000 years ago, preserved useful genetic variations that can be reintroduced through hybridization. Gene banks are valuable germplasm resources for breeding and essential for long-term sustainability (Priyanka et al., 2021). Advances in reproductive biology, storage techniques, and gamete use have furthered conservation efforts (Ballou et al., 2023). Key aspects of genetic diversity, stress factors, and their relevance for crop improvement are summarized in Table 1.

Table 1.

Key aspects of genetic diversity and relevance for crop improvement

Aspect	Impact / Challenge	Relevance for Breeding / Solutions	References
Genetic diversity	Enables adaptation to biotic and abiotic stresses	Foundation for selection and development of resilient cultivars	Salgotra & Chauhan, 2023
Climate change	Extreme temperatures, irregular rainfall, drought reduce crop resilience	Necessitates breeding of genotypes adapted to variable conditions	Swarup et al., 2021
Abiotic stress	Limits growth and yield; soil salinity is critical	Breeding for tolerance; management of environmental factors. Identification and utilization of tolerant genotypes	Toro et al., 2021
Genetic resource conservation	Risk of genetic erosion	Gene banks and modern reproductive techniques support sustainability and improvement	Priyanka et al., 2021; Ballou et al., 2023

Genetic resources and *Prunus* diversity

In Eastern Europe, particularly in the Balkans and Turkey, *Prunus* genetic resources are abundant. The most widespread species in Turkey include *Prunus domestica* L., *Prunus salicina* Lindl., *Prunus cerasifera* Ehrh., *Prunus insititia* L., and *Prunus spinosa* L., showing significant variation, especially in fruit and tree traits (Ilhan, 2023). Species also grow in southern China, northern Egypt, the southern United States, and desert climates of California, Spain, and Iran. *Prunus* species, especially plum and peach, have been cultivated for thousands of years (Rodríguez-Robles et al., 2024). The main aspects of *Prunus* genetic resources and diversity, including distribution, species, morphological and genetic variability, nutritional value, conservation, and adaptation to climate change, are summarized in Table 2.

Morphological and genetic analyses demonstrate variability across regions and species. For instance, Corrado et al. (2021) identified polymorphic traits in a germplasm collection from Campania, Italy, with the most diverse being fruit pulp color and Shannon Diversity Index (SDI). Basile et al. (2022) found the greatest diversity in fruit shape, followed by pulp color. Wild fruit species provide nutritional value (vitamins, minerals, antioxidants, fiber), medical, environmental, aesthetic, and economic benefits. In developing countries, wild fruit genotypes remain crucial for nutritional security. Climate change, population growth, and genetic erosion cause biodiversity loss, necessitating the collection, conservation, and sustainable use of wild plant resources. *P. domestica* and *P. salicina* have been cultivated for 4000–6000 years and remain the most widely grown *Prunus* species worldwide. Plums are rich in carbohydrates, fiber, tannins, flavonoids, anthocyanins, carotenes, and phenolic compounds. Some Chinese red plums contain anthocyanins up to 300 mg/100 g (Hamdani et al., 2023).

Table 2.

Summary of genetic resources and diversity in *Prunus* species

Category	Key Aspects	References
Distribution & Species	Eastern Europe (Balkans, Turkey), South China, North Egypt, Southern USA, desert regions (California, Spain, Iran); main species: *P. domestica*, *P. salicina*, *P. cerasifera*, *P. insititia*, *P. spinosa*	Ilhan, 2023; Rodríguez-Robles et al., 2024
Genetic & Morphological diversity	High variability across regions and species; polymorphic traits: fruit pulp color, fruit shape; high Shannon Diversity Index (SDI); clonal propagation reduces diversity, but diploid plums remain relatively diverse	Corrado et al., 2021; Basile et al., 2022; Zhebentyayeva et al., 2019; Yang et al., 2024
Nutritional Value & Uses	Wild and cultivated fruits rich in carbohydrates, fiber, antioxidants, flavonoids, anthocyanins; contribute to nutritional security and economic benefits	Hamdani et al., 2023
Conservation & Breeding	Traditional germplasm and gene banks essential for breeding: fruit quality, disease resistance, climate adaptability	Castro & Dejong, 2021; Priyanka et al., 2021; Ballou et al., 2023
Climate impact & Adaptation	Early flowering affects fertilization; genetic diversity crucial for adaptation to climate change	Li et al., 2022; Cosmulescu & Călușaru, 2020; Salama et al., 2021

Sottile et al. (2022) describe the genetic and varietal aspects influencing plum diversity and examine the opportunities for breeding. Plums rank second after peaches and nectarines in terms of importance; Romania and Serbia are the largest producers in Europe. The annual per capita consumption is low worldwide: Serbia – 27 kg, Bosnia and Herzegovina – 21.2 kg, Montenegro – 15.7 kg, Romania – 13.9 kg. Studies indicate that cultivated plum genotypes show relatively limited intraspecific genetic variability, though more extensive than other commercial *Prunus* species due to introgression from related species (Zhebentyayeva et al., 2019). Recent genetic studies show that cultivated diploid plums have a level of diversity similar to almonds, but higher than that of peaches or apricots. The limited variability results from clonal propagation, the small number of parent genotypes, and agronomic standardization, leading to the loss of old cultivars and genetic bottlenecks (Yang et al., 2024). Traditional germplasm (local cultivars, progenitor species) can play a crucial role in breeding, especially for fruit quality, disease resistance, and climate adaptability (Castro & Dejong, 2021). *Prunus cerasifera* (cherry plum or myrobalan) originates from Southeastern Europe and Western and Central Asia, showing great variability in vigor, temperature tolerance, ripening time, and disease resistance (Ternjak et al., 2024). The native distribution includes Southeastern Europe, Southwestern and Central Asia, up to altitudes 2200 meters; Ukraine and Romania are part of the native range, although some studies consider *P. cerasifera* to be of non-native origin. In Italy and the Czech Republic, it was cultivated before 1500 and is considered an invasive archaeophyte, occupying a wide range of rural and urban habitats (Czortek et al., 2024). Studies in Serbia, China, Romania, and Italy have evaluated the biochemical and morphological properties, revealing high genetic diversity (Miletić et al., 2005; Liu et al., 2008; Cosmulescu et al., 2018; Sottile et al., 2023). Phenological studies indicate that early flowering can result in floral organ damage and incomplete fertilization, emphasizing the negative impacts of global warming (Li et al., 2022; Cosmulescu & Călușaru, 2020; Salama et al., 2021).

Germplasm conservation and breeding strategies

Germplasm is a valuable resource, providing information on genetic composition and playing a crucial role in plant diversity conservation. It not only preserves unique alleles and trait combinations but also supports breeding, long-term evolutionary potential, and adaptive responses under changing environmental conditions. Key aspects of *Prunus* germplasm resources, conservation techniques, breeding programs, and genetic analysis tools are summarized in Table 3.

Table 3.

Conservation strategies and germplasm use in Prunus

Category	Key Points	References
Germplasm importance	Provides information on genetic composition; essential for maintaining plant diversity and unique cultivars; supports decentralized collections	Priyanka et al., 2021
Conservation techniques	Slow-growth cultures, cryopreservation, pollen and DNA banks; botanical gardens and genetic reserves; maintenance in farmers' fields	Priyanka et al., 2021
Breeding and utilization	Development of stress-resistant cultivars (winter, diseases) with improved yield and quality; SSR markers help analyze genetic variation despite polyploidy; requires coordinated efforts from botanical gardens, universities, governments, NGOs	Antanynienė et al., 2023; Walters & Pence, 2021

Protection strategies target both the rescue of threatened species and the wider conservation of all plant resources essential for human and ecosystem survival. Besides classical measures, modern tools are increasingly applied, such as slow-growth in vitro cultures to maintain genotypes, cryopreservation for extremely long-term storage, pollen and DNA banks to secure allelic diversity, as well as botanical gardens and genetic reserves that safeguard whole living collections. At the same time, on-farm conservation represents genuine "in situ" conservation, because evolutionary processes continue in those agroecosystems (recombination, local adaptation, farmer selection). All these techniques and approaches are complementary and are now viewed as core elements for effective plant genetic resource conservation (Priyanka et al., 2021).

Maintaining unique, well-documented cultivars is essential because it enables the establishment of a decentralized European plum germplasm collection and allows accurate comparison of phenotypic and genetic variability across different geographic and pedoclimatic contexts. In addition, modern breeding programs aim to generate new genotypes with superior resistance to harsh winter conditions, fungal diseases, and other biotic and abiotic stress factors, while simultaneously ensuring high yield potential and competitive quality parameters for the market. Therefore, in-depth analysis of genetic variation within germplasm collections becomes a critical component of biodiversity conservation strategies and provides an evidence base for informed selection decisions.

Furthermore, the complex polyploid nature of Prunus domestica complicates both genome sequencing and subsequent genomic interpretation, which has historically delayed the adoption of high-resolution molecular approaches compared to diploid species. Despite this challenge, SSR markers have nevertheless proven extremely useful for discriminating genetically similar individuals and for effectively differentiating homologous genomes, thus providing sufficiently high resolution for valid characterization of genetic diversity (Antanynienė et al., 2023). A sustainable world requires continuous efforts for plant biodiversity conservation, involving botanical gardens, universities, government agencies, and NGOs (Walters & Pence, 2021).

CONCLUSIONS

The variability of the *Prunus* genus is a fundamental element in maintaining and improving fruit production due to its extensive genetic diversity and high adaptability to diverse ecological conditions. This diversity offers valuable potential for cultivar selection and breeding, enabling the development of genotypes more resistant to biotic and abiotic stresses.

The adaptability of *Prunus* species to various soils and climates emphasizes the essential role of genetic resource conservation in both research programs and sustainable agricultural strategies. Rational use of this diversity becomes a priority to ensure resilience and sustainability of modern horticultural systems. Global studies also underline the importance of understanding adaptation mechanisms, providing essential scientific bases for genetic resource conservation, cultivar improvement, and the development of sustainable horticultural strategies.

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