INTROGRESSION OF WILD SPECIES IN EGGPLANT BREEDING AND MODERN BREEDING APPROACHES

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ABSTRACT
Eggplant (*Solanum melongena* L.) possesses a narrow genetic base, which limits its tolerance to various biotic and abiotic stress conditions. This limitation necessitates the use of wild *Solanum* species as strategic genetic resources to enhance genetic diversity in breeding programs. Studies in the literature report that introgression from species such as *Solanum incanum*, *S. torvum*, *S. aethiopicum*, and *S. anguivi* has led to significant improvements in disease and pest resistance, fruit quality traits, and stress tolerance (Gisbert et al., 2011; Plazas et al., 2016; Kaushik et al., 2020; Prohens et al., 2020). Techniques such as backcrossing, marker-assisted selection (MAS), QTL mapping, and genomic selection have been shown to increase the efficiency of introgression and accelerate the selection process (Barchi et al., 2019; Gramazio et al., 2017; Acquadro et al., 2020). This review provides a comprehensive evaluation of the current status of introgression in eggplant breeding, the challenges encountered, and the recent advancements in breeding programs.
Keywords: Eggplant, introgression, wild species, backcrossing, genomic selection,

PATLICAN ISLAHINDA YABANİ TÜR İNTROGRESYONU VE MODERN ISLAH YAKLAŞIMLARI

ÖZET
Patlıcan (*Solanum melongena* L.), dar genetik tabanı nedeniyle farklı biyotik ve abiyotik stres koşullarına karşı sınırlı dayanıklılık göstermektedir. Bu durum, yabani Solanum türlerinin ıslah programlarında genetik çeşitliliğin artırılması amacıyla stratejik bir kaynak olarak kullanılmasını gerekli kılmaktadır. Literatürde *Solanum incanum, S. torvum, S. aethiopicum* ve *S. anguivi* gibi türlerden yapılan introgresyon çalışmalarının, hastalık ve zararlı dayanıklılığı, kalite özellikleri ve stres toleransı üzerinde önemli iyileşmeler sağladığı bildirilmiştir (Gisbert ve ark., 2011; Plazas ve ark., 2016; Kaushik ve ark., 2020; Prohens ve ark., 2020). Geri melezleme, marker destekli seleksiyon (MAS), QTL haritalama ve genomik seleksiyon gibi yöntemlerin introgresyon verimliliğini artırdığı ve seleksiyon sürecini hızlandırdığı çeşitli araştırmalarda ortaya konmuştur (Barchi ve ark., 2019; Gramazio ve ark., 2017; Acquadro ve ark., 2020). Bu derleme, patlıcan ıslahında introgresyonun güncel durumunu, karşılaşılan zorlukları ve ıslah programlarındaki gelişmeleri kapsamlı biçimde değerlendirmektedir.
Anahtar Kelimeler: Patlıcan, introgresyon, yabani türler, geri melezleme, genomik seleksiyon

1. INTRODUCTION
Eggplant (*Solanum melongena* L.) is a vegetable crop belonging to the Solanaceae family, widely cultivated worldwide and possessing high economic value. However, selection from a limited number of genotypes during the domestication process has led to a narrowing of the

genetic base of cultivated eggplant (Daunay, 2008; Vorontsova & Knapp, 2012). This situation significantly restricts the adaptive capacity of eggplant to biotic and abiotic stress factors.
In eggplant production, *Verticillium dahliae*, *Fusarium oxysporum*, root-knot nematodes (*Meloidogyne* spp.), and various pests cause serious yield and quality losses (Rotino et al., 2014; Mutlu et al., 2015). In addition, abiotic stress factors such as drought, salinity, and high temperature have become increasingly important in eggplant cultivation due to climate change (Toppino et al., 2016; Yang et al., 2020). In this context, increasing genetic diversity in eggplant breeding has emerged as a fundamental requirement for sustainable production.

1.1. Role of Wild *Solanum* Species in Eggplant Breeding

Wild *Solanum* species possess much broader genetic variation and ecological adaptability compared to cultivated eggplant. These species have evolved under long-term selection pressures in their natural habitats and have acquired tolerance to multiple stress conditions (Vorontsova & Knapp, 2012; Gramazio et al., 2017).
Species such as *Solanum incanum*, *S. torvum*, *S. aethiopicum*, and *S. anguivi* are considered important genetic resources for eggplant breeding. The tolerance of *S. incanum* to drought and heat stress, along with its high phenolic compound content, makes it valuable for abiotic stress breeding (Kaushik et al., 2020). *S. torvum* is widely used both as a rootstock and as an introgression source due to its high resistance to root-knot nematodes and certain soil-borne pathogens (Gisbert et al., 2011; Schulz et al., 2019).
Solanum aethiopicum and *S. anguivi* also contribute significantly to eggplant breeding in terms of disease resistance, fruit firmness, phenolic content, and antioxidant capacity (Plazas et al., 2016; Prohens et al., 2013).

1.2. Introgression and Backcrossing Strategies

Introgression is one of the fundamental breeding strategies aimed at transferring target genes or genomic regions from wild species into cultivated eggplant. This process generally begins with interspecific hybridization, followed by repeated backcrossing of the obtained F_1 individuals with cultivated eggplant (Rotino et al., 2014). Backcrossing allows the elimination of undesirable genomic regions derived from wild species while stabilizing target traits in the cultivated genetic background.
However, genetic incompatibilities between species, low fertility, and embryo development problems are major factors complicating the introgression process. Therefore, auxiliary biotechnological techniques such as embryo rescue and bridge crosses are commonly employed, particularly in introgression studies involving genetically distant species (Gisbert et al., 2011; Toppino & Rotino, 2020).
In this context, *Solanum elaeagnifolium* is considered an important wild genetic resource in eggplant breeding, especially for adaptation to low nitrogen (N) input production systems. Studies evaluating advanced backcross generations (BC_2 and BC_3) containing *S. elaeagnifolium* introgressions under low nitrogen conditions have reported the development of lines exhibiting superior performance in terms of yield, nitrogen use efficiency (NUE), and phenolic compound content compared to cultivated eggplant (*Solanum melongena* L.). Furthermore, the identification of numerous QTL regions associated with morphological traits, fruit characteristics, and compositional properties such as stem diameter, prickliness, fruit width, and phenolic profiles demonstrates the significant potential of *S. elaeagnifolium* introgressions for low-input and sustainable eggplant breeding (Villanueva et al., 2021).
Similarly, *Solanum incanum* stands out as an important wild gene source for improving drought tolerance in eggplant. Studies evaluating introgression lines derived from *S. incanum* under water stress conditions have shown that certain wild alleles enhance drought tolerance through their association with increased stem and root dry weight. Positive effects of *S. incanum* alleles

on traits such as leaf water content, water use efficiency, and chlorophyll content traits that positively influence yield under drought stress have also been reported. These findings indicate that, together with fine mapping and advanced selection strategies aimed at reducing linkage drag, *S. incanum* introgressions possess high potential for improving drought tolerance in eggplant (Flores-Saavedra et al., 2025).

1.3. Molecular Breeding Approaches and Genomic Tools

In recent years, sequencing of the eggplant genome and the development of high-density molecular markers have led to significant progress in introgression studies (Hirakawa et al., 2014; Barchi et al., 2019). Marker-assisted selection (MAS) enables the identification of target genomic regions in early generations of backcrossing, thereby substantially shortening the selection process (Cericola et al., 2014).

QTL mapping studies have contributed to the identification of genomic regions associated with disease resistance, yield, and quality traits, with numerous QTLs reported particularly for fruit characteristics and stress tolerance (Portis et al., 2015; Frary et al., 2014). In addition, genomic selection allows more accurate and rapid selection for complex traits controlled by multiple genes (Acquadro et al., 2020; Gramazio et al., 2017).

1.4. Limitations Encountered in Introgression Studies

Although introgression breeding provides substantial opportunities for improving eggplant (*Solanum melongena* L.), its practical implementation is constrained by several biological and technical limitations. One of the most prominent challenges is linkage drag, which refers to the simultaneous transfer of undesirable traits from wild donor species together with target genes. These unwanted genomic segments may negatively affect agronomic performance, fruit morphology, and consumer-acceptable traits, thereby reducing the breeding value of introgressed lines (Cericola et al., 2014; Prohens et al., 2020).

In addition to linkage drag, interspecific incompatibility, reduced fertility, and hybrid breakdown are frequently observed in F_1 hybrids and early backcross generations. These reproductive barriers often result in low seed set, distorted segregation ratios, and prolonged breeding cycles, particularly when genetically distant wild species are used as donors (Rotino et al., 2014; Toppino & Rotino, 2020). Such limitations significantly increase the time and resources required to stabilize desirable traits in elite genetic backgrounds.

Another important constraint is the complex genetic architecture of stress tolerance and quality-related traits, which are typically controlled by multiple genes with small effects. This polygenic nature complicates phenotypic selection and increases the risk of retaining unfavorable alleles during the introgression process (Gramazio et al., 2017; Acquadro et al., 2020).

The integration of molecular markers and genomic tools has been shown to play a crucial role in mitigating these limitations. Marker-assisted selection (MAS) enables precise tracking of target alleles and facilitates the early elimination of unwanted donor genome segments, thereby reducing linkage drag (Barchi et al., 2019). Furthermore, high-density SNP genotyping and QTL mapping allow fine-scale dissection of introgressed regions, improving selection accuracy and efficiency (Portis et al., 2015; Frary et al., 2014). More recently, genomic selection approaches have emerged as promising tools for handling complex traits by capturing genome-wide effects, thus accelerating breeding progress in introgression-based programs (Acquadro et al., 2020).

2. CONCLUSIONS AND FUTURE PERSPECTIVES

This review presents the current status of introgression studies involving wild *Solanum* species in eggplant (*Solanum melongena* L.) breeding and highlights their role within modern breeding approaches. The reviewed literature demonstrates that genes transferred from wild species significantly contribute to increasing genetic diversity, improving tolerance to biotic and abiotic stresses, and enhancing yield and quality traits in eggplant.

Today, classical introgression breeding has become more efficient and targeted through integration with marker-assisted selection and advanced biotechnological approaches. Although still limited in application, genomic selection, high-density SNP markers, and genome editing techniques offer substantial potential for the transfer of beneficial alleles from wild species into cultivated eggplant and are considered promising tools that may enable faster and more controlled breeding processes in the future.

In conclusion, the effective integration of wild *Solanum* species into eggplant breeding programs holds great potential for supporting sustainable production and developing new cultivars resilient to the adverse effects of climate change. With the broader adoption of molecular and genomic approaches, accelerating genetic progress in eggplant breeding will become increasingly feasible.

References

Acquadro, A., et al. (2020). Genomic selection in eggplant. *BMC Genomics*, 21, 1–12.

Barchi, L., et al. (2019). High-density SNP genotyping in eggplant. *Scientific Reports*, 9, 1–12.

Cericola, F., et al. (2014). Linkage drag reduction in eggplant. *Molecular Breeding*, 34, 1601–1615.

Daunay, M. C. (2008). Eggplant, pp.: 163-220. Handbook of plant breeding: vegetables II. Springer, New York, NY, USA.

Frary, A., et al. (2014). QTL mapping of fruit traits in eggplant. *BMC Genomics*, 15, 1–15.

Flores-Saavedra, M., Gramazio, P., Vilanova, S., Mircea, D. M., Ruiz-González, M. X., Vicente, Ó., ... & Plazas, M. (2025). Introgressed eggplant lines with the wild *Solanum incanum* evaluated under drought stress conditions. *Journal of Integrative Agriculture*, *24*(6), 2203-2216.

Gisbert, C., et al. (2011). Interspecific hybridization in eggplant. *Euphytica*, 122, 57–64.

Gramazio, P., et al. (2017). Wild relatives in eggplant breeding. *Plant Cell Reports*, 36, 511-523.

Hirakawa, H., et al. (2014). Eggplant genome sequence. *DNA Research*, 21, 649–660.

Kaushik, P., et al. (2020). Drought tolerance in *Solanum incanum*. *Agronomy*, 10, 1–13.

Mutlu, N., et al. (2015). Verticillium tolerance in eggplant. *Euphytica*, 203, 181–193.

Plazas, M., et al. (2016). Resistance traits in *Solanum aethiopicum*. *Frontiers in Plant Science*, 7, 1–12.

Portis, E., et al. (2015). Genetic mapping in eggplant. *BMC Plant Biology*, 15, 1–14.

Prohens, J., et al. (2013). Phenolic content in *Solanum anguivi*. *Journal of Agricultural and Food Chemistry*, 61, 120–127.

Prohens, J., et al. (2020). Introgression breeding in eggplant. *Frontiers in Plant Science*, 11, 1–15.

Rotino, G. L., et al. (2014). Resistance introgression in eggplant. *Plant Breeding Reviews*, 38, 251–289.

Schulz, D., et al. (2019). Salt tolerance in Solanum rootstocks. *Plant Physiology and Biochemistry*, 140, 88–98.

Toppino, L., & Rotino, G. L. (2020). Hybridization barriers in eggplant. *Horticulture Research*, 7, 1–12.

Villanueva, G., Rosa-Martínez, E., Şahin, A., García-Fortea, E., Plazas, M., Prohens, J., & Vilanova, S. (2021). Evaluation of advanced backcrosses of eggplant with *Solanum elaeagnifolium* introgressions under low N conditions. Agronomy, 11(9), 1770.

Vorontsova, M. S., & Knapp, S. (2012). Taxonomy of wild eggplants. *American Journal of Botany*, 99, 1–21.

Yang, X., et al. (2020). Abiotic stress responses in Solanum species. *BMC Plant Biology*, 20, 1–13.

Toppino, L., & Rotino, G. L. (2020).Hybridization barriers and fertility constraints in eggplant. Horticulture Research, 7, 1–12.