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Green Fusion: Tailoring Crops for Yield and Stress Tolerance

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Global vegetable production, vital for human nutrition and food security, is increasingly threatened by the intensifying effects of climate change and aggressive agricultural practices. Facing challenges such as drought, salinity, extreme temperatures (abiotic stressors) and persistent soil-borne pathogens and pests (biotic stressors), producers worldwide are seeking rapid solutions. Vegetable grafting has emerged as a powerful and indispensable horticultural technology, often described as a "Green Surgical Fusion". This technique involves joining the tissues of two different plants to grow as a single, composite organism. The resulting plant leverages a high-yielding scion (the upper part, selected for superior fruit characteristics) with a robust rootstock (the root system, selected for vigor and resilience). This approach offers an immediate, non-transgenic solution to confer complex traits for stress tolerance to elite cultivars, moving beyond the slower pace and trade-offs inherent in conventional breeding.

The modern agricultural system is highly stressed, facing complex scenarios that severely limit growth and depress yields. The resulting yield gap is predominantly attributed to abiotic factors (approximately 70% of losses) and biotic factors (30%). Since traditional breeding methods are protracted and often compromise resistance while selecting for yield, the need for rapid, potent strategies to enhance crop resilience has become a critical imperative. Vegetable grafting offers an innovative solution by creating a composite organism designed for enhanced environmental performance. The main aim of this article is to review vegetable grafting as a climate-resilient strategy and synthesize knowledge demonstrating its potential as a climate adaptation tool for improving biotic and abiotic stress resistance while enhancing productivity.

Importance of Vegetable Grafting

- **Biotic Stress Management:** Grafting provides an eco-friendly and highly effective alternative to chemical soil fumigation for combating soil-borne pathogens and pests. Resistant rootstocks act as a "biotic filter" providing a barrier against fungal wilts (*Fusarium* and *Verticillium*), bacterial wilt (*Ralstonia solanacearum*) and root-knot nematodes (*Meloidogyne spp.*).
- **Abiotic Stress Tolerance:** Grafting engineers climate resilience. Rootstocks enhance drought tolerance through superior root architecture and hormonal signaling (*e.g.,* Abscisic acid production). They mitigate salinity stress by acting as a selective filter, excluding toxic ions like sodium (Na^+) and chloride (Cl^-) from the scion. Grafting also confers tolerance to extreme temperatures and waterlogging by promoting specialized anatomical adaptations like aerenchyma formation.
- **Enhanced Yield and Vigor:** By mitigating stress, grafting allows the high-yielding scion to allocate more energy toward reproduction. Grafted plants often show significant yield increases, commonly ranging from 20-40% in moderate stress conditions to over 60% in high-stress environments. Studies in India showed farmers reporting productivity increases ranging from 30% to as high as 150%.

Methods of Vegetable Grafting

The physical joining of the scion and rootstock is a precise procedure influenced by the plant species and stem diameter. Successful union requires careful post-graft care in a specialized healing chamber for 5-8 days to establish vascular connections. Such as

- **Splice Grafting:** The most widely used method for Solanaceous crops (tomato, pepper). It involves matching diagonal cuts secured by a clip. It is fast and simple, but requires nearly identical stem diameters.
- **Cleft Grafting:** The scion is cut into a V-wedge and inserted into a vertical slit in the rootstock. This technique is more forgiving of slight stem diameter differences and provides a secure union.
- **Hole Insertion Grafting:** Used commonly for Cucurbits (watermelon, cucumber). The scion is sharpened and inserted into a hole made in the rootstock stem after the growing point is removed.
- **Tongue Approach Grafting:** Slits are interlocked on two intact seedlings. The union heals before the scion is severed from its original roots. While highly successful, it is labor-intensive and slow.

Strategies to Enhance Grafting Technology

To maximize the potential of grafting, efforts are focused on overcoming limitations such as high costs, reliance on skilled labor and lack of rootstock diversity.

- **Next-Generation Rootstocks:** Future rootstocks must combine resistance to multiple biotic and abiotic stresses simultaneously. This involves exploiting wild relatives for valuable stress resilience genes. Biotechnologies like Marker-Assisted Selection(MAS) and gene editing (CRISPR-Cas9) can accelerate the breeding cycle by enabling rapid screening and targeted trait enhancement.
- **Automation and Robotics:** Automation is key to overcoming the high cost and skilled labor barriers. Grafting robots can perform between 400 and 1200 grafts per hour, far exceeding manual rates. Continued research is needed to develop more flexible and cost-effective robots that can handle slight variations in seedling size.
- **Integrated Systems:** Grafting is most effective when combined with protected cultivation. This integration buffers the crop from extreme weather and leverages the grafted plant's resilience to soil stresses, leading to the highest and most stable yields, as demonstrated by research in India.

Crop (Scion)	Rootstock Cultivar/Species	Primary Benefit(s)	Quantified Impact Example	References
Tomato (BHN 589)	Maxifort	High Yield, Vigor	41-60% increase in marketable yield	Lang *et al.*, 2020
Tomato (PHS-448)	*Solanum torvum*	Bacterial Wilt Resistance, High Yield	Upto 63.79% yield increase in polyhouse conditions.	Lang *et al.*, 2020
Eggplant	Huimei zhenba	Disease Resistance, High Yield	Bacterial wilt incidence reduced from 55.6% to 3.3%.	Bamaniya, 2024
Watermelon	*C. maxima* x *C. moschata* (Squash Hybrid)	Vigor, Cold/Drought Tolerance	Extremely vigorous root system supports high yields under stress.	Solankey *et al.*, 2021
Cucumber (Kashi Nutan)	Summerfit (SF)	High Yield, Photosynthetic Efficiency	80.9% increase in fruit yield.	Bahadur *et al.*, 2025

Conclusion

Vegetable grafting is fundamental to building a climate-resilient agricultural future. Its core strength lies in its ability to create a superior composite plant by uniting high-quality scions with robust rootstocks, a synergy underscored by the R x S x E interaction model. This technique functions as both a biotic filter against soil pathogens and an environmental sensor against abiotic stresses, leading to quantifiable yield increases and production stability. While challenges remain regarding high cost and labor requirements, the future is promising due to innovations in biotechnology (accelerated rootstock breeding) and automation (grafting robots). Continued investment and equitable dissemination of this powerful, environmentally sound technology are critical to securing a more productive and sustainable future for vegetable cultivation worldwide.

References

1. Lang, K. M., Nair, A., & Moore, K. J. (2020). The impact of eight hybrid tomato rootstocks on 'BHN 589'scion yield, fruit quality and plant growth traits in a midwest high tunnel production system. *HortScience*, *55*(6), 936-944.
2. Bamaniya, B. S. (2024). *Introgression of the Bacterial Wilt Resistance Gene into an Elite Eggplant (Solanum melongena L.) cultivated in Sikkim* (Doctoral dissertation).
3. Bahadur, A., Singh, A. K., Yadav, S., Kumar, R., Hare, K., & Behera, T. K. (2025). Inter-specific cucurbitaceous rootstock enhances plant growth, photosynthetic, root architecture and yield traits in grafted cucumber (*Cucumis sativus* L.). *Horticultural Science*, *52*(3), 237.
4. Solankey, S. S., Kumari, M., Akhtar, S., Singh, H. K., & Ray, P. K. (2021). Challenges and opportunities in vegetable production in changing climate: Mitigation and adaptation strategies. *Advances in Research on Vegetable Production Under a Changing Climate Vol. 1*, 13-59.