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Vegetable Grafting: A Potential Approach for Future Production

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Introduction

Vegetable grafting is a sophisticated horticultural practice that merges the vascular systems of a scion and rootstock to create a single more resilient plant. This technique is integral to modern intensive agriculture, particularly in combating biotic and abiotic stresses. Grafting confers enhanced resistance to soil-borne pathogens such as Fusarium and Verticillium wilts and provides tolerance to environmental stresses, including salinity, drought and temperature extremes. By utilizing rootstocks with specific desirable traits, grafting can significantly improve nutrient uptake efficiency and overall plant vigour, leading to superior yield and fruit quality. Furthermore, grafting is a pivotal strategy in reducing reliance on chemical inputs, contributing to more sustainable and eco-friendly farming practices. Advanced research in this field focuses on the molecular mechanisms governing graft compatibility, stress tolerance and the optimization of grafting techniques for diverse vegetable species. This technology is critical in addressing global food security challenges in the face of climate change.

Keywords: Grafting, Vegetable, its importance.

Introduction

Vegetable is required for maintaining a well-balanced diet in humans as they supply enormous quantity of dietary fibre, minerals, vitamins and phytochemicals. In Indian agriculture, vegetable play a key role in ensuring both nutritional and food security. Vegetables are known as the protected food due to its protective nature against various degenerative diseases. Added vegetable also plays a significant role in the economy helping the farmers to rise their standards. The varied agroclimatic condition in India round the year had made possible for growing a various type of vegetable crop year around throughout the country. The systematic vegetable improvement in India had been started since 1970 and later showed a tremendous improvement of vegetable production with regards to the world ranks and ranks

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2nd next to China. The production aspects are been greatly hindered due to the climate change. Vegetable crops are frequently exposed to various biotic (pest, diseases) and abiotic (drought, heat, temperature, salinity, radiation etc.,) factors that hampers the growth and productivity of the crop. One of the techniques for reducing the adverse impact for both biotic and abiotic stress is to graft the crops into a suitable rootstock that are capable to resist the stresses.

Vegetable grafting is a technique of vegetable propagation/asexual method that connects the two served segments of plant together. The chimera consists of the scion and the rootstock that survives as new individual after the wound healing. The natural grafting that occurs when the stem or the roots of the plant attaches and fuse together, had facilitated the invention of some of the new classical grafting techniques. The percentage of grafting success increases when there is a good compatibility between the rootstock and the scion. Several studies indicated that the compatibility is more when the grafting is done between different species that belongs to same genus compared to the grafts that belongs to the different genera of the same family. It is found that most of the homograft are compatible in nature with the exception to monocots as the vasculature are needed for maintaining water and nutrient transport. Most of the monocots are found without vascular cambia that might be the reason for the graft failures. Thus, vascular differentiation occurring during the process of wound healing is the prerequisite for successful graft union. Grafting in vegetable crops, had been started in the beginning of 20th century in Japan for controlling soil borne diseases where water melon was grafted onto the squash rootstock (Lee 2010).

Grafting Techniques

The rate of survival of the grafted plants chiefly depends upon the compatibility of rootstock and scion, age and quantity of the seedling, methods of grafting, the grafted section quality and the post grafting management. The process of grafting mainly involves four major steps, *viz*., Selection of scion and rootstock cultivars, choosing of appropriate grafting methods, graft union healing and acclimatization of grafted plant.

1. **Selection of scion and stock cultivars**.: They form the first and basic step for any grafting process. The scion cultivars are selected based on the viability, purity, yield, quality and market demand. The rootstock cultivars are more vigorous than that of the scion cultivars. The rootstock cultivar is selected based upon the viability, purity,

resistance to diseases, compatibility with scion cultivar and adaptability to local environment and soil condition.

2. **Grafting methods**: The methods that are opted for grafting a particular rootstock and scion depends on the grafting number required, grafting purpose, labour accessibility, infrastructure and machine availability etc., On whole, the grafting methods are divided into two categories i.e., manual and mechanical grafting. Although many of the machine and robots for grafting had been developed manual grafting is still practiced widely.
   - **One cotyledon grafting:** They are also known as slant or splice grafting. Here, first a 45-degree angle cut are given to rootstock where the cut removes the meristem tissue, one of the cotyledons and true leaves. Then the scion hypocotyl is cut as that of the rootstock. Here the scion is attached to the rootstock with grafting clip. They are more suitable in melon as they work best when the scion and stock have same hypocotyl diameter.
   - **Cleft grafting:** Cleft grafting that are practiced in the herbaceous plant differ from those of the woody plants. This method is used in the prevention of soil borne diseases as the junction of grafting is high on the hypocotyl. The rootstock is ready to graft in 7 to 10 days when the cotyledons and first true leaf emerges. The seedlings of the rootstock are decapitated and a longitudinal downward cut of 1-1.5 cm length and 3/4 depth are made. The scion is pruned to have 1-3 true leaves and the lower portion are cut below a slant angle to make tapered wedge. The scion is placed on the split of the rootstock where a clip is placed over it to hang it tight. Plants are kept in greenhouse until they get healed and are then transplanted. Cleft grafting is been used in cucurbits but recently they are confined to solanaceous crops too.
   - **Tongue approach grafting:** In this method the scion and rootstock must be of approximately in same diameter. Here the rootstock, have developed cotyledons and the scion are found with a cotyledons and first true leaf. A 45-degree cut are given downward that slit halfway through the stem that are below the cotyledons and in the scion, cut an identical angle upward slit. The location and the angle of cut should be of relatively precise so that the scion can be placed on the rootstock

top. The stem is brought together such that they overlap and for attaching, clip it or wrap it by using foil, parafilm or plastic wrap. The joined transplant is placed in a small pot or tray. Water the plants as and when needed. After 5 and 7 days, cut of the above portion of rootstock and below portion of the scion respectively. This method is been popularly practiced in crops such as melon, cucumber and watermelon (Mohanta 2015).

- **Tube grafting**: In this method both the rootstock and the scion are cut at 45-degree diagonal angle. Here both the cut is made below cotyledon as it decreases the suckering of rootstock after graft are healed. The two pieces now are joined together with the help of plastic parafilm or grafting clip. The grafted plants are taken into the healing chamber with the high relative humidity, low light environment and with 18 degrees minimum all time. Approximately after 7 days, the plants are removed from the chamber. Tomato grafts are done commercially using this method.
- **Pin grafting**: They are same as that of one cotyledon grafting with an exception that instead of grafting clips a specially designed pins are used for securing the graft union. The cotyledon of both the scion and the rootstock are cut horizontally and then a ceramic pin are inserted into the cut surface that aids to align and secure the joined sections. Further, after healing the grafted plants are transplanted.

3. Healing of grafts

Healing is the most critical for providing favourable condition to promote the callus formation of the grafted union in the healing chamber. The temperature should be of 28 to 29 degrees Celsius with relative humidity of 95% for 5 to 7 days in partially shaded places (1 to 2 days darkness) for promoting the formation of callus at the union. It helps for the formation of a better graft union by reducing the light intensity and transpiration, maintaining optimum temperature and high humidity.

4. Acclimatization of grafted plants

After the callus formation and healing of wound at surface, the plants are put under a mist chamber, greenhouse or placed under plastic cover to acclimatize the plants and preventing it from wilting and leaf burning.

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Importance of Vegetable Grafting:

Vegetable grafting is a critical innovation in horticulture that has transformed the production of high-value crops by combining the desirable traits of two plants: a scion, which provides the above-ground plant characteristics, and a rootstock, which enhances resilience and adaptability (Smith 2023). Below are key points illustrating its advanced importance with specific examples:

- Soil-Borne Disease Resistance: Grafting is a powerful tool for managing soil-borne diseases that severely impact vegetable crops. For instance, tomatoes grafted onto rootstocks like 'Maxifort' show significant resistance to Fusarium wilt, Verticillium wilt and Nematodes, reducing the need for soil fumigation and other chemical controls.
- Tolerance to Abiotic Stresses: Grafted plants can thrive in suboptimal environmental conditions. Eggplants grafted onto salt-tolerant rootstocks, such as 'EG203', have been shown to perform well under saline conditions, maintaining yield and fruit quality where non-grafted plants would suffer considerable losses.
- Enhanced Nutrient Uptake: Certain rootstocks are selected for their superior nutrient absorption capabilities. For example, cucumbers grafted onto '*Cucumis moschata*' rootstocks exhibit improved nitrogen and phosphorus uptake, leading to higher biomass production and fruit yield, especially in nutrient-poor soils.
- Yield and Quality Improvement: Grafting can directly contribute to increased yield and improved fruit quality. In the case of melons, grafting onto rootstocks like 'Shintoza' results in larger, more uniform fruits with better sugar content and firmness, which is critical for market acceptance and transportability.
- Sustainability and Reduced Chemical Usage: Grafting reduces reliance on chemical pesticides and fertilizers. For example, pepper plants grafted onto disease-resistant rootstocks eliminate the need for multiple fungicide applications, leading to a more sustainable and environmentally friendly production system.
- Extended Growing Seasons: Grafting enables crops to be grown in off-seasons or in regions with shorter growing seasons. Tomatoes grafted onto cold-tolerant rootstocks can be planted earlier in the spring, allowing for an extended harvest period and better market positioning.

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- Preservation of Soil Health: Continuous cropping of the same vegetables can lead to soil degradation. Grafting allows crops like watermelons to be grown in the same field year after year without the adverse effects of soil fatigue, as resistant rootstocks prevent the buildup of soil pathogens.
- Improved Plant Vigor and Growth: Grafted plants often show enhanced vigor, which translates to faster growth and earlier maturity. For example, bell peppers grafted onto 'Robusto' rootstocks exhibit increased stem thickness and root mass, leading to better overall plant health and earlier fruiting.
- Targeted Trait Combination: Grafting allows for the combination of specific traits from different plants. For example, a flavorful heirloom tomato scion grafted onto a hybrid rootstock can result in a plant that produces high-quality fruits with the vigor and disease resistance needed for commercial farming.
- Pest Management: Grafting can also provide protection against pests. For instance, cucumbers grafted onto squash rootstocks can resist cucumber beetles more effectively due to the rootstock's natural pest-deterrent properties.
- Resource Efficiency: In water-scarce regions, grafted plants often exhibit better water use efficiency. Tomatoes grafted onto drought-tolerant rootstocks like 'Beaufort' can maintain productivity with less water, making them ideal for arid and semi-arid regions.
- Adaptation to Climate Change: Grafting is a strategic tool for mitigating the effects of climate change. As temperature fluctuations become more common, using rootstocks that confer heat tolerance, such as certain *Capsicum species for peppers, ensures consistent crop performance.
- Economic Benefits: The economic impact of grafting is significant, as it allows farmers to produce higher yields of premium-quality vegetables with lower input costs. For example, grafted watermelon plants typically yield 20-30% more fruit per acre than non-grafted ones, providing a substantial return on investment.

Conclusion

Vegetable grafting represents a transformative paradigm in contemporary horticultural science, integrating advanced physiological and molecular strategies to address the complexities of global agricultural challenges. By exploiting the synergistic interactions between scion and rootstock, this technique confers enhanced resistance to biotic and abiotic stresses, optimizes nutrient acquisition, and enables cultivation under suboptimal conditions, thereby significantly bolstering crop resilience and productivity. Moreover, grafting's capacity to mitigate environmental impact through reduced agrochemical usage and its adaptability to climate-induced pressures underscores its strategic relevance in sustainable agriculture. As the global demand for food intensifies amid climatic volatility, the continued evolution and precision of grafting methodologies will be critical in driving the next generation of agricultural innovation and ensuring long-term food security.

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