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GRAFTING TECHNIQUES IN VEGETABLE CROPS

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Grafting is the process of joining plant parts through tissue regeneration, resulting in a physical union that grows as an independent plant. It typically involves inserting buds or stems of a desired scion into a rootstock, produced either by seed or vegetative means, ensuring alignment of cambium tissues to form a successful graft union.

Historical background

- Grafted plant production began in Japan and Korea in the late 1920s using watermelon scions on bottle gourd rootstocks to combat yield decline from soil-borne diseases.
- In Korea, grafting was practiced on a small scale by farmers from the early 1950s.
- By 1959, brinjal scions were widely grafted onto *Solanum integrifolium* rootstocks to manage soil-borne diseases like *Verticillium* wilt, *Fusarium* wilt, bacterial wilt, and nematodes.
- During the 1960s, commercial grafting of cucumber and tomato began in Japan and Korea.
- By 1990, grafted plant usage in fruit vegetables covered 59% of the area in Japan and 81% in Korea.
- Currently, nearly all greenhouse-grown cucurbits in Korea and Japan are produced through grafting.

Purpose of grafting

In greenhouses, grafting onto resistant rootstocks is the most effective solution to manage soil-borne diseases and nematodes (since the spores of many pathogens enter through roots), as soil solarization alone is insufficient.

(a) Disease tolerance. Effective against diseases like: Fusarium wilt in cucurbits (Fig.1) and tomato, *Phytophthora* in pepper, Viral diseases in tomato

- **'Shintozwa'** (hybrid of *Cucurbita maxima* × *C. moschata*) is widely used for:
  - Strong resistance to all four fusarium races
  - Tolerance to low soil temperature and salinity
  - Good compatibility with watermelon, melon, and cucumber
- **Bottle gourd**:
  - Used for watermelon
  - Susceptible to Fusarium race IV
  - Poor compatibility with melons

- **Cucurbita ficifolia**:
  - Tolerance to low soil temperature
  - Used for summer squash in winter greenhouses
- Other rootstocks like ash gourd, bur cucumber, and African horned cucumber are under limited use/testing for nematode resistance.

(b) Yield increase.

- In oriental melon, fresh fruit weight increases by 25–55% when grafted, compared to own-rooted plants. Yield enhanced due to plant vigour
- Grafting onto 'Kagemusia' and 'Hilper' rootstocks increases marketable yield by 54% and 51%, respectively.
- In tomato, grafting also reduces abnormal fruit bearing compared to own-rooted plants.

(c) Low temperature tolerance.

- Grafting watermelon, melon, cucumber, and summer squash onto low temperature-tolerant rootstocks (e.g., *Cucurbita maxima* × *C. moschata*) reduces growth inhibition caused by low soil temperature in winter greenhouses.
- Cucumber grafted on fig leaf gourd (*Cucurbita ficifolia*) grows faster than own-rooted plants due to better water and nutrient uptake at low soil temperatures.
- Grafted seedlings help minimize many physiological disorders effectively.

(d) Reduced fertilizer and agrochemical application.

- Most rootstocks for cucurbits have larger and stronger root systems than scion varieties.
- To prevent excessive vegetative growth and poor fruit quality, fertilizer rates for grafted cucurbits should be reduced to one-half to two-thirds of that used for own-rooted plants.
- The frequency of agrochemical application can be significantly reduced by using vigorous rootstocks
- Deficiency symptoms may be minimized with proper selection of rootstocks.

Table 1. Direct and Indirect response of grafting technique in Vegetable crop

Direct Response	**Indirect Response**
Disease tolerance	Shoot growth promotion
Low temperature tolerance	Juvenile and adult phase changes
High temperature tolerance	Translocation studies of stimuli
Enhanced mineral uptake	Sex expression
Salt tolerance	Hormonal regulation
Increasing fertilizer efficiency	Physiological changes or disorders
Enhanced water uptake	Wet soil tolerance
Organic substances translocation	Root nodulation
Propagation and transformation	Fruit yield and quality
Winter hardiness	Heritable changes or agent
Xylem sap composition	Ornamental value
Nematode resistance	Earliness, size control, extended harvest

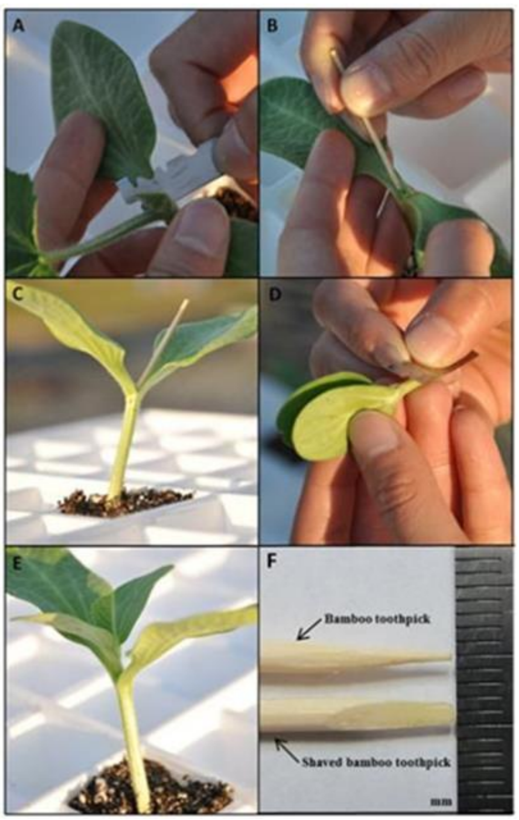
Species and varieties for grafting

- Grafting is a commercial in herbaceous plants mainly cucurbitaceae, Solanaceae
- I.generic- cucumber on pumpkin, watermelon on bottle gourd, muskmelon on ash gourd
- I.specific grafting- Brinjal (Rs- *S. integrifolium, S. torvum*)

Methods of grafting for fruit bearing vegetables

Method of grafting depends on the kind of crops being grafted, preference and experience of the growers, and the kind or grafting machines or robots available.

(1) Hole insertion grafting (HIG)



- Widely used in commercial grafting due to no need for clipping, transplanting, or clip removal.
- Requires more skill than tongue approach grafting (TAG).
- Ensures stronger seedlings by enabling better vascular connection.

Watermelon

- Suitable for watermelon due to smaller seedling size compared to rootstock (squash/bottle gourd).
- **Seed Sowing Schedule**: Watermelon (scion): sown 7–8 days after bottle gourd Rs and 3–4 days after squash Rs.
- **Grafting Time**: Performed 7–8 days after watermelon sowing when seedlings are uniform and sturdy.

  Procedure:

  - Remove the true leaf and growing point of the rootstock.
  - Make a slant hole in the rootstock using a bamboo/plastic gimlet or drill (Fig. 2).
  - Cut the watermelon hypocotyl at a slant to form a tapered end for insertion.
  - Avoid penetrating into stem pith to ensure proper union and to avoid adventitious root formation from scion into soil after downward elongation via pith cavity of rootstock

Tomato and Brinjal

- **Seed Sowing**:
  - Rootstock: sown 5–10 days before the scion.
  - Grafting: done 20–25 days after scion sowing.

  Procedure:

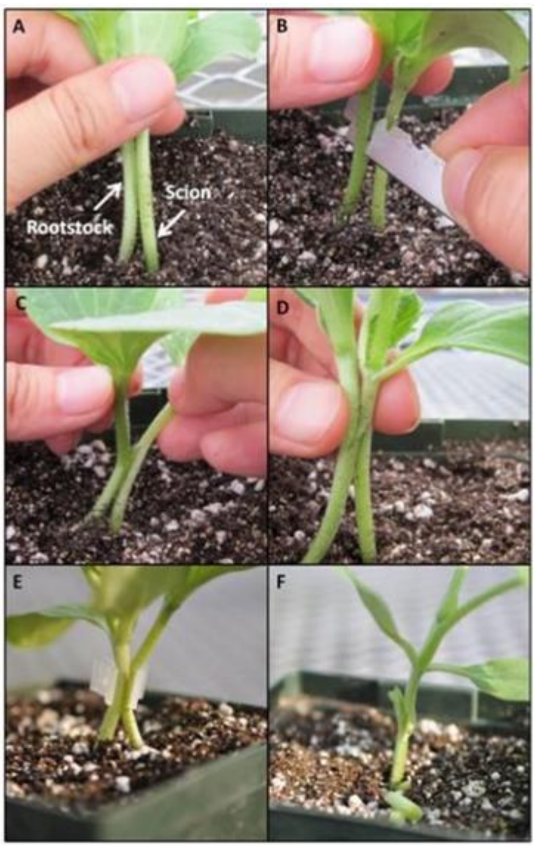
  - Rootstock with 2–3 true leaves is decapitated 5–10 mm above the first node.

- A slant hole is made in the rootstock stem.
- Scion with 2 true leaves is cut 10 mm below the cotyledonary node and shaped into a tapering wedge.
- Insert the scion into the rootstock hole.

Post-Grafting Care:

- Place grafted plants in a high humidity chamber.
- Ensure optimal healing conditions for rapid union: high humidity, high temperature, and adequate light.

2. Tongue Approach Grafting (TAG)



Common Users:

- Preferred by less experienced farmers
- Suitable for those without advanced greenhouse facilities

Advantages:

- Does not require special equipment or controlled environment
- Higher seedling survival rate, even for beginners
- Convenient and oldest method for herbaceous plant grafting
- Widely used in cucurbits (e.g., watermelon, muskmelon, cucumber)

Procedure:

1. Seed Sowing: Sow scion seeds 5–7 days before rootstock seeds to match height

2. Rootstock Preparation: Remove growing point and sometimes one cotyledon to reduce nutrient loss and overcrowding

3. Cutting Technique: Make downward cut on rootstock and upward cut on scion at 30–40° angle to the perpendicular axis. Ensure cuts allow maximum vascular contact (Fig.3)

4. Grafting: Join cut surfaces and fix with grafting clips. Grafted plants are then planted together in 9–12 cm pots

5. Healing Stage: Partially shade plants for 1–2 days before full greenhouse exposure

6. Post-union Care: Remove root and lower hypocotyl of scion near graft union. Remove clips shortly before transplanting

Limitations (for commercial use):

1. High labour requirement for grafting, pruning, and clip removal
2. Requires more growing space
3. Risk of scion rooting if transplanted too deep

(3) Splice grafting

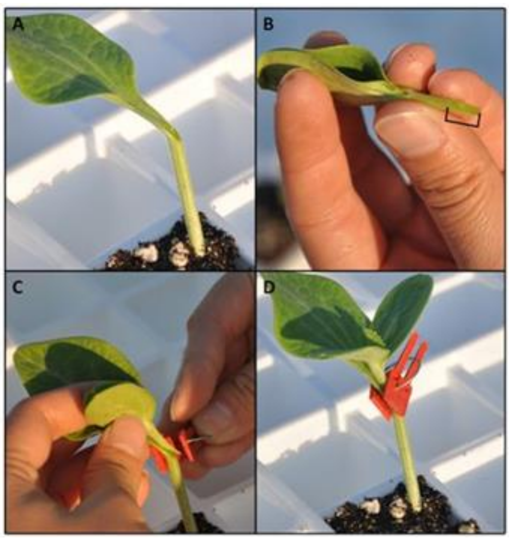
Users: Popular among experienced growers and commercial seedling nurseries

Applicability:

- Suitable for most vegetable crops
- Can be performed manually, mechanically, or robotically

Advantages:

- Produces strong, healthy seedlings
- Ensures complete fusion of vascular bundles
- Graft union withstands rough post-grafting handling



Procedure:

- **Cucurbits:** Remove one cotyledon and growing point from rootstock, Place scion over rootstock, Secure using ordinary grafting clips (Fig. 4)
- **Solanaceous crops:** Graft at lower epicotyl region, Use clips (ordinary, elastic tube-type with side slit, or ceramic pins) to hold union

4. Cleft Grafting

- **Seed Sowing:** Sow rootstock seeds 5–7 days before scion seeds
- **Seedling Stage for Grafting:**

  Scion: At fair-leaf stage (retain 2–3 leaves)

  Rootstock: At 4–5 leaf stage (retain 2–3 leaves)
- **Cutting Technique:** Cut both scion and rootstock stems at right angles. Shape scion base into a wedge. Make a cleft at the top of rootstock stem
- **Grafting:** Insert scion wedge into rootstock cleft. Secure the graft union using a plastic clip

5. Pin Grafting (Similar to splice grafting in technique)

- **Main Difference:** Uses **specially designed ceramic pins** instead of clips to hold the graft union
- **Material Used:** Pins made of **natural ceramic**, safe to remain on the plant without causing harm
- **Limitation:**

  Ceramic pins are **very expensive**

  Due to high cost, **alternative grafting methods** are being adopted

6. Tube Grafting

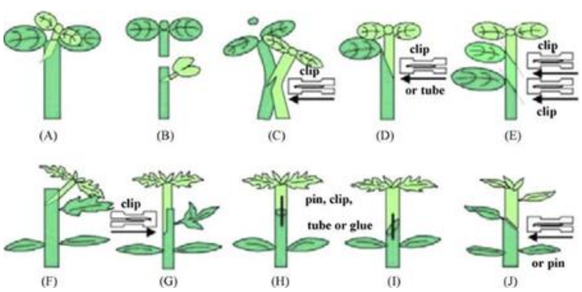
- **Advantages:** Allows grafting of small plug tray seedlings **2–3 times faster** than conventional methods. Enables **high-density healing** in chambers due to smaller plant size. Widely used by **Japanese seedling growers**
- **Growth Stage Consideration:** Optimal grafting stage depends on **plug tray size**. Smaller cells → earlier grafting stage and smaller tube diameter required
- **Procedure:** Cut **rootstock** and **scion** at matching slants. Join both using an **elastic side-slit tube.** Tube holds scion and rootstock firmly for graft healing

7. Micro-grafting

- Definition: In vitro grafting using very small explants (< 1/1000th mm^3) from meristematic tissues
- Purpose: Mainly used to eliminate viruses, as apical meristems are virus-free.
- Helps study the physiology of grafting and cell-to-cell interactions
- Applications:

  Rapid propagation of virus-free plants

  Used in research on herbaceous crops
- Limitation: High cost makes it less practical for routine commercial use



Major grafting methods in cucurbits and solanaceous vegetables: (A and B) hole insertion grafting; (C) tongue approach grafting; (D, E and J) splice grafting; (F, G) cleft grafting; (H and I) pin grafting.

Monitoring Grafting Success

A. Traditional Methods:

- Visual observation by experienced growers/researchers
- Transverse cut across graft union to inspect internal healing

B. Modern Objective Methods (for mass propagation):

1. Electrical Resistance Measurement:

Detects vascular reconnection based on resistance levels

In Tomato:

Day 2–3: Resistance increases due to isolation layer formation

Next 3-4 days: Resistance decreases as callus develops and as isolation layer dissolves

Then: Resistance returns to normal → indicates vascular unification

In *Amaranthus tricolor / Lycopersicon esculentum*:

Resistance remains high if isolation layer stays unbroken

2. Thermal Imaging (Leaf Temperature):

Successful grafts show 2–3°C lower leaf temperature due to active transpiration

Indicates smooth water transport from rootstock to scion

Seedlings with thicker leaves retain moisture better → support faster graft union

3. Hydraulic Connection Assessment:

Measured using displacement transducer to evaluate water movement

4. Electrical Wave Transmission:

Measures signal continuity between scion and rootstock

Useful for assessing graft integration at cellular level

Robotic grafting

The first grafting robot, the "Cutting-off Cotyledon Grafting" (CCG) system, was developed in Japan by IAM BRAIN for cucurbits, achieving a 95% survival rate and completing one graft in three seconds. Various grafting aids like reusable clips, tapes, ceramic pins, and specialized knives (including virus-inactivating ones) are widely used.

Healing and acclimatization

- Healing and acclimatization are done in plastic tunnels with silver/white cheese cloth (outside) and transparent film (inside) to maintain shade and humidity.
- Maintain light intensity at 3–5 klx, temperature around 30°C, and relative humidity above 95% during the first 3 days during healing & acclimatization.

Precautions for grafting

- Expose scion and rootstock to sunlight for 2–3 days.
- Withhold water to prevent spindly growth.
- Ensure stem diameters of scion and rootstock are similar to maximize cut contact
- Gradually reduce humidity and increase light after healing.
- Keep tunnel temperature constant; foliar water spray helps prevent wilting.
- Adjust shading based on daily weather conditions.

Effects of Grafting

1. **Vigour:** Grafting can enhance scion growth and yield through vigorous rootstocks, though some may reduce it.
2. **Physiological Disorders:** Rootstocks may induce fruit or leaf abnormalities like reduced TSS, yellow mottling in tomato, or abnormal fruit fermentation in muskmelon.
3. **Stress Tolerance:** Grafting improves tolerance to temperature extremes, drought, flooding, and salinity—especially beneficial for cucurbits in low soil temperatures.
4. **Higher yield, reduced inputs,** and suitability for **organic and hydroponic** cultivation.

Problems Associated with Grafted Plants

- Requires skilled labour and careful post-graft management.
- Risk of **unexpected diseases** like virus infection in rootstock seeds.
- **Secondary diseases** may occur, such as anthracnose in bottle gourd or TMV in tomato.
- Issues like **poor vascular fusion**, seasonal graft incompatibility, and reduced fruit quality.
- **Fruit quality deterioration** includes reduced firmness and shelf-life.
- Involves **additional costs** for rootstock seeds, grafting operations, and equipment.

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