Biology of rootstock/scion interactions

Prof. Dr. Károly Hrotkó

SZIU Faculty of Horticultural Science
Importance of rootstock/scion interactions in horticulture

- Tree size control (growth, vigour, morphology, growth habit)
- Influence on cropping (turning to bearing, productivity, crop or fruit quality)
- Influence on phenology and development stages (juvenility, senescence, longevity)
- Wide adaptability to site as well as abiotic and biotic stress factors

*The rootstock usage is essential in modern fruit and winegrape growing.*
Basic factors in rootstock usage:

- The genom of composite tree components doesn’t change, so the graft involves the treats of rootstock and scion partners: treats of composite trees are widened.

- Due to the metabolic interactions in the phenotype of scion modifications occur (positive and negative modifications are possible).
Rootstock treats in composite trees important for growers

- Treats in morphology: rootstock shank stability, root system position, branching of root system, anchorage in soil.
- Adaptability to abiotic factors: soil structure, compactness, drainage, water content, water logging, drought tolerance, tolerance to high and low temperature, winter hardiness.
- Tolerance or resistance to biotic factors: nematodes, soil born fungi (Rosellinia, Roessleria, etc.), bacteria (Agrobacterium)
Modifications in scion phenotype caused by rootstock

- Vegetative production: tree size, growth habit, growth intensity and dynamics.
- Phases in phenology: sprouting, flowering, closing shoot growth, leaf fall, dormancy stages.
- Stages of development: turning to bearing, senescence, longevity.
- Generative productivity: flowering capacity, fruit set, cropping.
- Fruit quality: ripening, size, color, storability, inner content.
- Oeco- and pato-resistance: winter hardiness, cold tolerance (indirect effects), rootstock effects on pests and disease resistance, tolerance.
Scion also affects the rootstock!

- Very few knowledge in this field.
- Root spread, branching, depth.
- Root growth intensity and dynamics.
- Cold tolerance of roots and winter hardiness.
Possible mechanisms in rootstock/scion interactions
(Faust 1989)
Possible role of graft union in metabolic transport (Webster 1997)
Possible role of graft union in metabolic transport in interstocks (Webster 1997)
Known factors causing the rootstock/scion interactions

- Correlative balance within the plant.
- Different intensity and dynamics in linked metabolic processes.
- Changes in translocation capacity (water, minerals, assimilates).
- Different intensity and dynamics in production of phytohormones, differences in translocation of hormones.
- Transmission of genetic information between the graft components: mRNA, proteins.
- Disturbing and inhibiting compounds, unknown and unacceptable metabolics in heterografts.
Different intensity and dynamics in linked metabolic processes

- Nutrient uptake and translocation (xylem transport)
- Uptake of water and transport
- Differences in carbohydrate metabolism and transport (phloem transport)
Leaf nutrient content of ‘Van’ sweet cherry trees on different rootstocks (Szigetcsép 1993)
Changes in translocation capacity

- Differences between rootstock and scion in xylem transport capacity.
- Differences between rootstock and scion in phloem transport capacity.
- Screening effect of graft union on concentration of minerals (K, Ca, Mg, Fe, Zn) and organic matters in xylem sap.
- Accumulation of assimilates above the graft union in scion bark.
Xylem transport

- Water flow (sap flow): \( E = d \ \Psi_w / R \) (Lakso 2003) (differences in water potential / resistance)

- Considerable ratio of hydraulic resistance is caused by root (Landsberg and Jones 1981) (rootstock of heterografts!)

- Possible rootstock factors:
  - Trachea lumen surface in root cross section of vigorous apple rootstocks is much larger compared to dwarf ones: less hydraulic resistance, faster translocation;
  - Disturbances in vessels, ‘bottlenecks’ in tracheas disturb the transport, sapflow velocity increases.

- Due to senescence lignification may tighten the tracheas.
Trachea lumen surface in shoots of cherry cultivars and rootstocks

<table>
<thead>
<tr>
<th></th>
<th>Germers-dorfi óriás</th>
<th>Van</th>
<th>Colt</th>
<th>SL64</th>
<th>MxM 14</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Trachea pc/cm²</strong></td>
<td>242</td>
<td>195</td>
<td>166</td>
<td>170</td>
<td>166</td>
</tr>
<tr>
<td><strong>Average trachea surface mm²</strong></td>
<td>0.002</td>
<td>0.001</td>
<td>0.0014</td>
<td>0.0012</td>
<td>0.0008</td>
</tr>
<tr>
<td><strong>Trachea lumen mm²/cm²</strong></td>
<td>0.484</td>
<td>0.195</td>
<td>0.232</td>
<td>0.204</td>
<td>0.128</td>
</tr>
</tbody>
</table>
Phloem transport

- Phloem / xylem ratio of roots in dwarfing apple rootstocks is larger.
- In contrary the phloem in dwarfing cherry rootstocks is thinner (Feucht 1982).
- In dwarfing cherry rootstocks the sieve tube ratio is half compared to mazzard (Tanrisever és Feucht 1977)
- Phloem transport velocity in dwarf rootstocks is smaller (Forche 1972)
- Graft union may form difficulties >>> starch accumulation above the graft union (swelling, overgrowth)
Basipetal transport of $^{32}$P in intergrafted apple rootstock trunks (Forche 1972)

<table>
<thead>
<tr>
<th>Combination</th>
<th>Velocity cm/hours</th>
<th>Combination</th>
<th>Velocity cm/hours</th>
<th>Combination</th>
<th>Velocity cm/hours</th>
</tr>
</thead>
<tbody>
<tr>
<td>M.11 M.11</td>
<td>19.9</td>
<td>M.11 M.7</td>
<td>12.2</td>
<td>M.11 M.11</td>
<td>8.1</td>
</tr>
<tr>
<td>M.11 M.11</td>
<td>16.4</td>
<td>M.7 M.7</td>
<td>9.2</td>
<td>M.7 M.9</td>
<td>6.1</td>
</tr>
<tr>
<td>M.9 M.11</td>
<td>9.2</td>
<td>M.9 M.7</td>
<td>6.2</td>
<td>M.9 M.9</td>
<td>5.1</td>
</tr>
<tr>
<td>M.9 M.9</td>
<td>6.2</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
Differences in production and translocation of hormone

- **Auxine**: produced in scion (shoot tip and young leaves) and translocated in the phloem of scion and rootstock shank into root system.
- **Citokinin**: produced in rootstock part, in root tips and transported in xylem sap towards the canopy.
- **Actual auxin/citokinin ratio determine:**
  - Apical dominance
  - Sprouting of dormant buds,
  - Branching angle of laterals.
- **Gibberellic acids**: production is not localized, transported in xylem sap > cell growth, elongation of internodes.
- **ABA**: causes senescence of cells and tissues, decrease of function potential.
Possible hormonal interactions in phloem and xylem translocation of cherry

Shoot tip growth: seasonal differences by rootstock

Auxin in young leaves; no rootstock influence?

Auxin translocation in phloem

Auxin in graft union

Translocation capacity through graft union

Translocation in rootstock phloem

Leaf growth

Protection or decomposition affected by phenolics (catechin), IAA-oxidase, peroxidase. Seasonal differences by rootstock.

Control of sieve tube formation → compatibility

Protection or decomposition affected by rootstock phenolics IAA-oxidase, peroxidase. Seasonal differences

Exceed balance → Prunin: < incompatibility potential

Scion shoot Graft union

Transport in rootstock xylem

Branching habit affected by balance of IAA, Citokinine, (GA?)

Citokinin formation in root tips

Root growth affected by balance between the actual IAA supply and genetic determinated optimum

Progress in rootstock research
Possible role of GA (gibberellic acids) and ABA (abscisic acid)

- M.9 apple rootstock contains lower GA and higher ABA level.
- Injection of GA into trunk increased growth vigour.
- Injection of ABA into trunk decreased vigour.
Dwarfing effect of apple rootstocks located in the (phloem) bark?

- Lockard és Schneider (1981): Bark (phloem) of MM.111 changed for M.26 >>> dwarfing effect occured.
- Phloem in root and rootstock shank of M.9 is thicker, more living, parenchimatic cells.
- Larger rate of phenolic compounds >> increased decomposition of auxine
- Role of solar radiation? (budding height)
Rootstock position of Idared trees at the different planting depth

![Bar graph showing rootstock position at different planting depths and light exposure levels. The x-axis represents light levels (+20, +10, +0, +35, +20, +5), and the y-axis represents cm depth. Bars are color-coded: red for covered in soil and yellow for light exposed.](image-url)
Prof. Dr. Károly Hrotkó  
Rootstock scion interactions
Growth (TCSA cm$^2$) in 10$^{th}$ year
Yield efficiency (kg/TCSA cm²) in 10th year
Mean fruit weight on trees with differently exposed rootstock shank (1999)
Graft union on M. 26 and MM. 106 rootstocks
Graft union of Idared / B.9 / MM. 111 interstems

+ 5 cm  + 20 cm  + 35 cm
Possible reasons for decreasing dwarfing effect in covered rootstock shank?

- Decomposition of auxine is reduced? GA production and transport is modified?
- Positive effects of auxine-protecting phenolic compounds found in etiolated stem? (Davies and Hartmann 1988, Englert et al. 1991)
- Reduced ABA production in etiolated stem – slow down the senescence? (Hartmann et al. 1997)

Optimal exposition of rootstock shank – important tool for growers in growth control.
Transmission of genetic information between grafting partners

- Transmission of specific regulating proteins and mRNA is possible using plasmodesmata connection in grafting union (Transmission of Me mutation of tomato using grafting)

- The mRNA are mobile in phloem.
Disturbing and inhibiting compounds, unknown and unacceptable metabolics in heterografts, or missing specific compounds
Graft incompatibility

- When differences in metabolic system of composite tree and/or changes caused by rootstock effects are larger that could be tolerated by modification capacity of grafting partners
  >>> disfunction occure
  >>> lead to *incompatibility*
Incompatibility during graft union formation

- Defficiency in decomposition of necrotic layer.
- Recognition and adhesion of cells by lectine in contact zone is not satisfying.
- Disturbances in vessel differentiation in contact zone (cambial ring, xylem and phloem).
- Disturbances, disfunction in linked vessels.
- Disturbances in linked metabolic systems of scion and rootstock.
Anatomical difficulties in graft union resulting in graft incompatibility

- At Prunus species (cherry) difficulties in differentiation of phloem sieve tubes (Schmid and Feucht 1981). Caused partly by low hormonal or carbohydrate supply.
- Apricot on plum rootstocks: vessels are formed but the callus never differentiate completely (Errea et al 1994).
- At apple parenchymatic callus tissue remain in xylem >> week graftin union on Mark rootostock (Warmund et al 1993)
- Delayed incompatibility: apricot on myrobalan, certain conifers and oaks show similar symptoms.


Visible symptoms of graft incompatibility not always indicate incompatibility!

- Low bud take rate in the nursery.
- Difficulties in graft union formation, short living combinations.
- Smooth surface of broken graft union on older trees.
- Overgrowth of scion or rootstock at graft union, differences in growing dinamycs.
- Suckering rootstock (not consequently indicates incompatibility).
- Early leaf coloring and leaf fall.
- Stunting growth, dying trees.
Classification of graft incompatibility by Herrero (1951)

- Mechanical: components split due to mechanical force
- Physiological
- Delayed
Types of physiological incompatibility (Hartmann et al. 1997)

- **Localized**: linked to contacting components, when components are separated doesn’t occur (Bartlett/Hardy/Quince)

- **Translocated**: when components are separated by interstock, which is compatible with both partner, incompatibility occurs between compatible partners (Hale’s Early/Myrobalan B), starch accumulation at Brompton/Myrobalan B union.
Virus induced incompatibility

- Stem pitting, Stem grooving at apple, pear

- Hypersensitive reaction:
  NRV – Prune Dwarf: at cherries

- Hypersensitive reaction:
  Cherry Leaf Roll: black line disease at walnut
Testing, prediction of incompatibility

- Anatomical investigation at graft union?
- Callus growing test in vitro?
- Comparison of izoenzym-structures?
- Comparison of protein profiles (electrophoretic mobility of proteins)?
- Comparison of genetic fingerprint?

- Graft partner combinations charged with incompatibility may not show symptoms under optimal conditions, while environmental stress supports appearance of symptoms!
Incompatibility of Bartlett / Quince

<table>
<thead>
<tr>
<th>Quince rootstock</th>
<th>Bartlett scion</th>
</tr>
</thead>
<tbody>
<tr>
<td>Produces prunazin (HCN-glükozid)</td>
<td>No prunazin production</td>
</tr>
<tr>
<td>Transport in xylem &gt;&gt;&gt;</td>
<td>Glycosidase enzym splits prunazin &gt;&gt;&gt; HCN + glucose</td>
</tr>
<tr>
<td>Disturbances in phloem transport to roots</td>
<td>&lt;&lt;&lt; HCN poisons the cambium, phloem and xylem is degenerated</td>
</tr>
<tr>
<td>Difficulties in root nutrition &gt;&gt;&gt; produces more prunazin</td>
<td>Free HCN causes phloem necrosis at graft union</td>
</tr>
<tr>
<td>Intergrafting of Beurre Hardy, Old Home &gt;&gt;&gt;</td>
<td>Compatible pear cultivars produce an enzyme blocking glycosidase &gt;&gt;&gt; no splitting prunazin</td>
</tr>
</tbody>
</table>