Partitioning of Carbohydrates and Development of Tissues in the Graft Union of Peaches Grafted on *Prunus tomentosa* Thunb. Rootstock

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**Summary**

Carbohydrate partitioning and graft union development of peaches grafted onto *Prunus tomentosa* Thunb. were compared with the one on *Prunus persica* (L.) Batsch.

The low total dry matter confirmed the dwarfing effects of *P. tomentosa*. The distribution (%) of dry matter was lower in the new leaves and shoots compared with that on *P. persica*, but the root dry matter distribution tended to be higher for the former rootstocks. That the roots are a sink for carbohydrates was demonstrated by the translocation of labeled $^{13}$C, which was found mainly in the small roots of dwarfing rootstocks.

The carbohydrate content showed that the main sugar present is sorbitol which followed a similar pattern in both rootstocks. The carbohydrate contents in peaches on dwarfing rootstocks were lower in the new shoots and tended to be higher in the roots; the starch content in roots, branches, and leaves of dwarfing rootstock was higher than that in the peach stock.

During the first months the graft union on both rootstocks was characterized by the development of similar callus and cambial cells, with connective vascular cambium, but in the dwarfing rootstock necrotic cells were observed in the callus and in the new xylem of scion. The graft union zone of dwarfing rootstocks, two and four years after budding, showed necrotic points in the xylem of rootstocks which were rarely observed in vigorous rootstocks. Thinner vessels were observed in the intergraft zone on dwarfing rootstocks. The xylem elements orientation lost a normal pattern, and vessels in swirling shape were observed in the intergraft zone on both rootstocks.

These observations indicate that necrosis in the graft union was brought about by some substances produced by the scion or rootstock, which accumulated because of a disfunctional vascular system. Hence, the poor scion-rootstock relationship affected growth.

**Key Words:** *Prunus tomentosa*, dwarfing, peach, grafting.

**Introduction**

*Prunus tomentosa* Thunb. (Nanking cherry), when used as a rootstock for peach, dwarfs the scion; however, the dwarfing is accompanied by symptoms that are attributed to graft incompatibility, (Ferree, 1988; MAFF, 1988; Andrews and Serrano, 1992).

The dwarfing phenomenon in apple has been related to many morphological and physiological factors, (Lockard and Schneider, 1981; Olien and Laks, 1984; Simons and Chu, 1984; Soumelidou et al., 1994a). Among the factors considered is the carbohydrate partitioning because there is evidence that the translocation of carbohydrates may be affected by stock and scion combinations (Kubota et al., 1990; Gaudillere et al., 1992).

In an incompatible peach/plum grafts combination, lower sorbitol concentration was found in the roots than in those of a compatible graft, whereas more soluble sugars and starch accumulated in the peach scion of the incompatible one. Moing and Gaudillere (1992) concluded that carbohydrate concentrations provided an direct evidence that carbon transfer to the roots was hindered in the incompatible graft.

Another aspect related to the dwarfing mechanism is the tissue development in the graft union (Simons and Chu, 1984, 1985; Soumelidou et al., 1994a; Ussahatanonta and Simons, 1988). These studies showed that the graft union develops abnormal vascular tissues and that the different degrees of necrosis within the graft union were associated with dwarfism (Simons and Chu, 1985). In apples, smaller vessels were found at the union between scion and dwarfing rootstock, indicating the presence of elevated levels of auxin in this region (Soumelidou et al. 1994b). The necrosis is also attributed to substances which are produced in the rootstocks and transported to the scion, where they break down, producing toxins (Moore, 1984).

This study was aimed to determine if differences in vegetative vigor of peach trees on rootstocks *P. persica* and *P. tomentosa*, could be related to carbohydrate partitioning and to the graft union development in this particular scion-rootstock combination.
Materials and Methods

Carbohydrate partitioning

Three, 4-year-old trees of peaches cv. Kansuke Hakuto grafted on P. persica or P. tomentosa, were dug up on July 11 and separated into fruit, leaves, new shoots (current season’s shoot), branches, trunk, zone of graft union (4 cm), and roots. The number of fruits per tree was approximately 40 and 14 for vigorous and dwarving rootstocks, respectively. Five fruits per tree of each rootstock were taken for analysis. The samples were dried in an oven at 70 °C to determine the dry weight; representative portions of each part of the tree were submerged in liquid nitrogen and stored at -80 °C until used. Samples were blended in liquid nitrogen and a 2 g aliquot was extracted 3 times with 50 ml of 80% ethanol. The ethanolic extracts were evaporated in vacuum at 40 °C to water phase and then passed through ion exchange resins columns (Amberlite IR-120B for cation and Amberlite IRA-400 for anion). The residual protein was precipitated with Ba(OH)2 and ZnSO4 and the mixture was filtered. The filtrates were adjusted to 200 ml. Twenty milliliters of sample were dried, redissolved in 1 ml of 1,000 ppm pentasterthritol, an internal standard, for gas chromatography (GC), and stored in a 15 ml vial in a desiccator for over 2 days. The samples were silylated by adding 1 ml pyridine, 0.4 ml hexamethyldisilazane (HMDS) and 0.4 ml trimethylchlorosilane (TMDS) to the sample and heated. The mixtures were then injected into a gas chromatograph (Shimadzu GC-9AM) with Silicone Gel SE-52 Chromosorb W (AW-DMCS) column and a flame ionization detector (FID).

Starch was determined on the sugar-free residues after drying at 60 °C for at least 3 days. A 0.5 g of dry sample was hydrolyzed with 20 ml of 0.7 N HCl in a hot bath for 2.5 hours. The mixture was neutralized by titration with 0.1 N NaOH and the protein was treated as above with Ba(OH)2 and ZnSO4. The volume of the resultant extract was adjusted to 200 ml. For starch analysis, a 1 ml sample was transferred into a test tube to which 6 ml anthrone reagent (200 mg of anthrone powder mixed with 95 ml conc. H2SO4 and 5 ml water in a cold water bath filled with ice) was added. The mixture was heated for 10 minutes at 98 °C in hot water and then cooled. Starch in the sample was quantified by a UVVIS spectrophotometer (Jasco, U-best-35, Japan Spectroscopic Co. Ltd. Tokyo) at 620 nm wavelength.

To follow the translocation of carbohydrates, 2-year-old trees grown in plastic containers were administered 13CO2 derived from barium carbonate-13C at atom 99% (11 g per chamber). On July 26, two trees per rootstock were put into an airtight film chamber (1×1×1.6 m). The 13CO2 was released by adding acetic acid (50%) with a syringe to solid barium carbonate-13C within the chamber. The hole was immediately sealed.

After 6 hours of feeding, the trees were removed from the chamber and 120 hours after feeding, the trees were separated into leaves, new shoots, branches, scion trunk, rootstock trunk, graft union, small roots (< 2 mm) and large roots (>2 mm).

Small portions of each part of the tree were lyophilized and powdered. The 13C atom (%) in the samples was determined with an automated 15N 13C analyzer (Anca®-SL, Europe Scientific).

The absorption of 13C was calculated as follows. The natural concentration of carbon in the dry matter was considered to be 1.1%; consequently, the 13C (%) in each sample was calculated as: 13C atom (%) -1.1%.

13C partitioning for each plant organ was calculated as: dry matter of each organ (g) × carbon ratio in the sample (%) × 13C atom excess (%) (Kubota et al., 1990; Tatsumi et al., 1992). Percent partitioning for each organ was calculated as the ratio between the amount of 13C in an organ and the total of 13C in the plant.

The values were analyzed individually for each tree on each rootstock.

Observations of tissue development

Buds of cv. Kansuke Hakuto and cv. Akatsuki were budded onto P. persica and P. tomentosa, in September of 1994. The trees of cv. Akatsuki were provided by a nursery. The development of the bud unions was followed by sampling each rootstock-scion combination at 1, 3, and 7 months after the budding. Also, one-year-old trees of cv. Kansuke Hakuto, budded onto the same rootstocks, were planted in plastic containers and samples of three graft unions of each rootstock-scion combination were examined in the second growing season (July 1995).

The graft union was observed 4 years after grafting on field grown trees of cv. Kansuke Hakuto grafted on the same rootstocks. Samples of three graft unions of each rootstock-scion combination were collected in summer; and the excised samples fixed in FAA (formalin: acetic acid: 60% ethanol, 5 : 5 : 90) solution.

The samples were sectioned directly and then stained with acid fuchsin (1%) and fast green (0.1%). Transverse and longitudinal sections of 24 μm thickness were made of the union tissues with a microtome. The sections were observed by a light microscope (Olympus BH-2).

Results and Discussion

Dry matter and partitioning of carbohydrates

Dry matter

In 4-year-old trees, the total dry matter assimilated by P. persica on its own rootstock was four times higher than that of P. persica/P. tomentosa combination. The dry matter of the top, above the graft union, represented by the trunk, branches, new shoots, and leaves
followed the same pattern as that of total dry weight. When the dry matter distribution is expressed as the proportion between the dry matter in each organ and the total dry matter, the fruits, roots and graft union on *P. tomentosa* accumulated relatively more than comparable organs on the *P. persica* stock; however, the dry matter distribution into new shoots and leaves was reversed (Table 1).

In 2-year-old cv. Kansuke Hakuto trees grown in plastic containers, more dry matter went to small roots of *P. tomentosa* than into those of *P. persica*, indicating that the roots of dwarfing rootstocks accumulated relatively more carbohydrates. This implies that the partitioning of carbohydrates to the roots is influenced by the rootstocks.

**Content and partitioning of carbohydrates**

The total carbohydrates assimilated as represented by the sum of carbohydrate contents in each part of the tree (Fig. 1), showed that trees on *P. persica* rootstock

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**Table 1.** Dry matter (g) in different parts of 4-year-old and 2-year-old cv. Kansuke Hakuto trees grafted onto *P. persica* and *P. tomentosa*.

<table>
<thead>
<tr>
<th>parts of trees</th>
<th>Fruits</th>
<th>Leaves</th>
<th>New shoots</th>
<th>Branches</th>
<th>Trunk</th>
<th>Graft union</th>
<th>Roots</th>
<th>Total</th>
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<tr>
<td></td>
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<td></td>
<td>Large roots (&lt; 2 mm)</td>
<td>Small roots (&lt; 2 mm)</td>
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<td>4-year-old tree</td>
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<tr>
<td><em>P. tomentosa</em></td>
<td>262.8 ± 31.9</td>
<td>153.1 ± 43.7</td>
<td>32.9 ± 7.1</td>
<td>67.8 ± 36.5</td>
<td>261.7 ± 78.5</td>
<td>29.7 ± 11.1</td>
<td>229.3 ± 49.9&lt;sup&gt;y&lt;/sup&gt;</td>
<td>1037.9 ± 236.2</td>
</tr>
<tr>
<td>distribution %</td>
<td>25.3</td>
<td>14.8</td>
<td>3.2</td>
<td>6.5</td>
<td>25.2</td>
<td>2.9</td>
<td>22.1</td>
<td></td>
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<tr>
<td><em>P. persica</em></td>
<td>587.1 ± 119.1</td>
<td>666.3 ± 55.6</td>
<td>299.1 ± 13.6</td>
<td>298.9 ± 41.4</td>
<td>1349.2 ± 262.3</td>
<td>57.2 ± 10.9</td>
<td>847.8 ± 56.9&lt;sup&gt;y&lt;/sup&gt;</td>
<td>4106.1 ± 391.5</td>
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<tr>
<td>distribution %</td>
<td>14.3</td>
<td>16.2</td>
<td>7.3</td>
<td>7.3</td>
<td>32.8</td>
<td>1.4</td>
<td>20.6</td>
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<tr>
<td>2-year-old tree</td>
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<tr>
<td><em>P. tomentosa</em></td>
<td>12.6 ± 0.4</td>
<td>1.9 ± 0.2</td>
<td>6.2 ± 2.1</td>
<td>49.9 ± 6.3</td>
<td>5.6 ± 0.05</td>
<td>44.5 ± 7.3</td>
<td>13.0 ± 2.3</td>
<td>133.5 ± 3.6</td>
</tr>
<tr>
<td>distribution %</td>
<td>9.4</td>
<td>1.4</td>
<td>4.6</td>
<td>37.3</td>
<td>4.2</td>
<td>33.3</td>
<td>9.7</td>
<td></td>
</tr>
<tr>
<td><em>P. persica</em></td>
<td>20.8 ± 3.8</td>
<td>2.1 ± 0.1</td>
<td>10.2 ± 3.9</td>
<td>164.6 ± 32.7</td>
<td>15.4 ± 3.6</td>
<td>132.8 ± 10.3</td>
<td>16.7 ± 1.1</td>
<td>362.4 ± 53.2</td>
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<tr>
<td>distribution %</td>
<td>5.7</td>
<td>0.6</td>
<td>2.8</td>
<td>45.4</td>
<td>4.2</td>
<td>36.6</td>
<td>4.6</td>
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<sup>a</sup> Data represent mean ± standard error of three replications
<sup>y</sup> The roots were not divided in small and large roots

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**Fig. 1.** Partitioning of carbohydrates content in different parts of 4-year-old cv. Kansuke Hakuto peach trees grafted onto *P. persica* and *P. tomentosa*.
accumulated 446.25 mg/g dw, whereas those on *P. tomentosa* contained 407.50 mg/g dw. The data on partitioning of carbohydrate revealed that in the aerial portion (above the graft union) of the tree of dwarfing rootstock combination, the branches and scion trunk stored 12.08 and 12.18%, respectively; while the carbohydrates in the fruits, leaves and new shoots amounted to 9.27, 14.9 and 19.9%, respectively. The total carbohydrate content in roots of trees on *P. tomentosa* was 11.67% compared to that on *P. persica* which was 9.7%. These data coincided with the findings by Brown et al. (1985) and Kubota et al. (1990).

Among the different parts of a tree, sorbitol was the predominant form of sugar in leaves and in new shoots on both rootstocks. In dwarfing rootstocks, the sorbitol in the scion and graft union tended to be higher than that on the vigorous ones. Also in the dwarfed trees, the starch content in the aerial parts, i.e., leaves and branches was higher than that on the vigorous rootstocks. Moing et al. (1990) also found higher soluble sugar and starch contents in the leaves in peach/plum incompatible graft combination.

Gur and Samish (1968) proposed a theory about metabolism of carbohydrates and their relation with the dwarfing phenomenon; the bark of the more dwarfing apple stocks had a higher rate of auxin destruction than had the bark of the less dwarfing clones. IAA plays an active role in metabolite mobilization; apparently, it is involved in the conversion of starch into more active forms of carbohydrate. The role of IAA in the metabolism of carbohydrates may be important in the dwarfing phenomenon caused by certain apple rootstocks, because the more dwarfing stock has a higher starch content (Colby, 1935).

Fruits were sampled at an immature stage, 2 or 3 weeks before normal harvest. The immature fruits on dwarfing rootstocks, nevertheless, had an unusually high starch content but a low sucrose content when compared to the amounts found in fruits on the vigorous peach rootstocks.

The reason for the low sugar content of fruit on dwarfing rootstocks is not clear, but the paucity of sugars may reflect the lack of enzyme activity in the conversion of starch to sugar.

Starch accumulation in the leaves during periods of high rates of photosynthesis may indicate that sucrose export may be lagging behind the rate of photosynthesis; it may also be the result of reduced sink demand for assimilates or preferential control toward starch synthesis (Daie, 1985).

**Translocation and partitioning of $^{13}$C-photosynthates**

More $^{13}$C labeled assimilates were found mainly in the scion leaves and trunk of the tree on both rootstocks, but we observed that small roots in the dwarfing rootstock had a higher $^{13}$C count (0.74%) than those on vigorous rootstocks (0.24%). In addition, the weight of the $^{13}$C fraction in the small roots was 51 mg and 19 mg for dwarfing and vigorous rootstocks, respectively (Fig 2.). Similar results were reported by Kubota et al. (1990).

Daie (1985) explained that the carbohydrate distribution pattern in a plant is related to the relative competitive ability of the various sink regions within the whole plant. A high sink import rate is a function of its mobilizing ability. If the sink mobilizing ability, or strength is a function of sink size and activity, then amounted $^{13}$C labeled fraction found in small roots on dwarfing rootstocks could indicate its high sink activity.

Morinaga and Ikeda (1990) also found that citrus trees, which showed graft incompatibility, had a high carbohydrate distribution ratio to roots, whereas those

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**Fig. 2.** Partitioning of labeled $^{13}$C carbohydrate in different parts of 2-year-old cv. Kansuke Hakuto peach trees grafted onto *P. persica* and *P. tomentosa.*
on vigorous rootstocks had a lower distribution ratio.

Observations of graft union development

One month after grafting

The first response of the tissues to grafting is the development of callus cells, which occurs on the cut surfaces between rootstocks and scion. The parenchymatous cells produced from cells at the cut end of ray xylem cells formed homogeneous masses which was stained strongly. The xylem elements near the cut surfaces were discolored and the vessels were filled with gum; also necrotic tissues were observed in the old xylem of the scion.

The callus cells lying between the cut ends of the cambia of bud and rootstock differentiated into cambial cells. The new meristematic cells were aligned horizontally joining the cambium of stock and scion, but where there were no tangential alignment, the new cambial cells acquired a sinuous shape.

In transverse sections at this stage the bridging vascular cambium formed new xylem in the intergraft. The xylem elements tended to be oriented in a different direction from the normal xylem (Fig. 3, A).

Three months after grafting

In transverse sections, new generating and connective tissues were observed and the new xylem elements had a perpendicular orientation with respect to the stem axis. The callus cells, yet observable, were surrounded by a necrotic layer (Fig. 3, B). The new xylem which developed in the rootstock zone showed necrotic lines and isolated pockets of necrotic cells (Fig. 3, C).

Seven months after grafting

The longitudinal sections across the graft union revealed necrotic cells in the callus at the base of the scion (Fig. 3, D). The new xylem orientation was different in the intergraft zone, compared with xylem in other parts. No necrotic lines of cells were observed on graft union on vigorous peach rootstock.

Based on these observations of graft union we conclude that peach trees on both P. tomentosa and P. persica develop callus and cambial cells similarly. In the initial stages of graft formation, normal vascular cambium from the callus was formed between the stock and scion to unite the two components. The orientation of the newly formed vascular tissues is a prerequisite for a successful union which could affect the growth of scion; new vascular elements require 2~3 years of growth to assume a normal longitudinal orientation (Simons and Chu, 1985). In the vigorous peach rootstocks used in this experiment, necrosis in the xylem and in callus was not systematically observed as they were on dwarfing rootstocks. In the latter, small necrotic areas were present within the developing tissues between the stock and scion as the graft grew. Simons and Chu (1985), who found tissue malfunctions and necrosis in M26 apple rootstocks, concluded that if necrosis persisted and became accentuated, vascular continuity would be impaired.

Observations of 2-year-old graft union

A strongly stained necrotic cell layer was observed surrounding the xylem of dwarfing rootstock (Fig. 3, E). This coincides with the findings of Simons and Chu (1984).

In the longitudinal sections, the xylem elements which originated from the callus were oriented horizontally. In dwarfing rootstocks, the parenchymatous cells were in ordered alignment, but the vessels were S-shaped at the intergraft zone (Fig. 3, F).

A necrotic cell layer between the rootstocks and scion, consisting of different sizes and fewer vessels, were observed (Fig. 3, G).

Usahatanonta and Simons (1988), likewise, found variations in the rootstocks exhibiting a more dwarfing characteristics; the phloem had a swirling pattern, while the xylem rays were abnormally oriented and different degrees of necrotic cells occurred within the graft union.

Observations of 4-year-old graft union

In 4-year-old graft unions necrotic zones in the xylem are visible in transverse section of Kansuke Hakuto' on P. tomentosa (Fig. 3, I). The necrosis was accompanied by vessels with abundant resin and occurred in the majority of samples on dwarfing rootstocks with increasing age, but rarely present in vigorous rootstock. The symptom was prevalent below the cut zone of graft union and in the rootstock trunk, but not in the scion trunk above the graft union. This indicates that some substances from the rootstock or the top accumulated in this zone which, in turn, produced this abnormal characteristic.

In the transverse sections of dwarfing rootstock, numerous thin vessels were observed in the intergraft zone, and a necrotic layer existed between the old and new xylem of the stock (Fig. 3, J). The new xylem elements appear disoriented with respect to its normal pattern in the old xylem; vessels with different sizes and shapes were also visible.

The new xylem elements of the rootstocks became strongly stained, especially those surrounding necrotic pockets. The number of vessels close to this zone was reduced, and some vessels had resins.

Contrarily, in the vigorous peach rootstock, the intergraft zone showed swirling xylem elements and vessels with resins which could indicate that in dwarfing rootstocks of peaches, the swirling and orientation were not
factors related directly to the dwarfing phenomenon. However, the necrotic points in the xylem and the necrotic layer in the intergraft zone may be factors that influence the vascular tissue development to cause an alteration in the normal flux of endogenous hormones or affect the supply of water and nutrients to the scion. The necrotic points could be caused by substances produced by the rootstocks.

It is well known that auxin is involved in the vascular development by limiting and controlling both phloem and xylem differentiation (Aloni, 1987a, b). The abnormal xylem differentiation observed here could be related to auxin deficiency or excess but other factors may be involved because this symptom is prevalent in vigorous rootstocks.

The necrosis which was found in the xylem could indicate the presence of some substances produced in the stock and accumulated in the graft union. These materials could act as physical barrier by inducing the production of resin in the vessels which impedes the normal flux of hormones and photosynthates; these substances may also be toxic. Polar transport of hormones is impeded by harmful metabolites such as cyanides or phenols (Rubery, 1987). Some researchers have concentrated on the rootstock bark as the essential cause of dwarfing. Thus, Jones (1984) proposed that bark of different rootstocks may influence the quantities of auxin passing down to the root in such a way as to produce differential effects on root development and cytokinin synthesis.

**Fig. 3.** A-J: Microscopic observation of graft union of peaches cv. Kansuke Hakuto on *P. persica* and *P. tomentosa* rootstocks.

- A: Transverse section through 1-month-old bud union of *P. tomentosa* with cv. Kansuke Hakuto. The new bridging cambium (head of arrow) formed new xylem. The arrow indicates necrotic lines in the old xylem of the scion.
- B: Transverse section through 3-month-old bud union of *P. tomentosa* with cv. Kansuke Hakuto. The new bridging cambium and new xylem with elements in abnormal orientation are observed. The head of arrow indicates strongly stained cells in the callus zone.
- C: Transverse section through 3-month-old bud union of *P. tomentosa* with cv. Akatsuki. Arrows indicate lines of necrosis in the new xylem.
- D: Longitudinal section through 7-month-old bud union of *P. tomentosa* with cv. Kansuke Hakuto. Head of arrow indicates necrotic lines at the base of scion.
- E: Transverse section through a 2-year-old union of *P. tomentosa* with cv. Kansuke Hakuto. The xylem of rootstocks is surrounded by necrotic layers (arrow).
- F: Longitudinal section through a 2-year-old union of *P. tomentosa* with cv. Kansuke Hakuto. Head of arrow shows callus elements in an ordered alignment.
- G: Longitudinal section through a 2-year-old union of *P. tomentosa* with cv. Kansuke Hakuto. In the intergraft zone necrotic layer and vessels showing different sizes and orientation are observed.
- H: Longitudinal section through a 2-year-old union of *P. persica* with cv. Kansuke Hakuto. Arrow shows swirling of vessels and fibers.
- I: Transverse section through a 4-year-old union of both rootstocks (Left, *P. persica*; Right, *P. tomentosa*). This sector corresponds to the rootstocks just below the graft union. In the trunk of dwarfing rootstocks (right) necrotic points are visible in the xylem.
- J: Transverse section through a 4-year-old union of *P. tomentosa*. Close to the union graft, rust-colored cells were surrounded by necrotic layer. Head of arrow indicates the xylem orientation and discolored cells.

R, rootstock; S, scion; V, vessels; C, cambium; X, xylem; I, intergraft zone; n, necrosis. Bar=0.1 mm

**Literature Cited**


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矮性台モモ樹における炭水化物の分配と接木部における組織発達

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摘要

ユスラウメ（Prunus tomentosa）台モモ樹（矮性台桝）の炭水化物の分配と接木部の発達を、共台桝と比較し、検討した。各部位の乾物重は、新葉と新梢では矮性台桝と比べて共台桝で高かったが、根では矮性台桝で高い傾向があった。13C光合成産物の各部位への転流を調査した結果、根で高いシンク活性がみられた。その部位に微量に認められた、蒸散量であるソルビトールの各部位における含量は、両台桝の間に差がなかった。矮性台桝の総炭水化物含量は、共台桝と比べて新梢で低く、逆に根で高い傾向があった。また、根、側枝、葉のデンプン含量は矮性台桝で高い傾向があった。

接木1カ月後に、両台桝の接木部にカルスおよび台木穂柄間を連絡する導管形成層の発達が観察されたが、矮性台桝ではカルスの周りや新生木部中に頭死組織がみられた。接木2〜4年後には、矮性台桝の接木部では新生木部に頭死組織が観察されたが、共台桝ではほとんどみられなかった。矮性台桝の接木部では導管が細く、木部要素の発達方向にも異常がみられた。また、両台桝でらん状の導管が観察された。

これらの結果から、接木部の頭死組織は台木の生産する何らかの物質の接木部への蓄積と関係し、そのことが穂柄の生長に影響するものと推察された。