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Rootstock Influences Seasonal Dry Matter and Carbohydrate Content and Partitioning in Above-ground Components of 'Flordaprince' Peach Trees

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ABSTRACT. **Seasonal development of leaf area, leaf area index (LAI), dry matter, and carbohydrate content were measured from harvest 1992 to harvest 1993 in above-ground components of 'Flordaprince' peach [*Prunus persica* (L.) Batsch] trees grafted on GF 677 (*Prunus persica* x *Prunus amygdalus*) and MrS 2/5 (*Prunus cerasifera* free pollinated) rootstocks, which widely differ in vigor. Whole trees were separated into fruit, leaves, shoots, 1-year-old wood and >1-year-old wood. Sampling dates were coincident with key fruit and tree developmental stages: dormancy, fruit set, pit hardening, and fruit harvest. Rootstock modified the vegetative vigor of the tree, the seasonal partitioning of dry matter, and starch content in above-ground components. Leaf area, LAI, and total above-ground dry matter were twice as high in the most vigorous combination ('Flordaprince'/GF 677), which gave the highest yield, but had the lowest harvest index. Rootstock vigor did not affect soluble sugar concentration in any of the canopy components. Starch content was greatest during dormancy and in the oldest wood of GF 677 trees. During fruit development, starch content rapidly decreased in 1-year-old wood and perennial components; at pit hardening it was four times greater in MrS 2/5 than in GF 677 trees. The vegetative-to-fruit dry mass ratio by pit hardening was 3:1 for MrS 2/5 and 9:1 for GF 677 trees. Competition with shoot growth apparently reduced fruit growth, particularly during Stage I and Stage II, as fruit size at harvest was significantly lower (17%) in GF 677 than in MrS 2/5 trees.**

Assimilate accumulation and partitioning among sinks in peach trees depends on tree age (Chalmers and van den Ende, 1975), seasonal growth pattern of vegetative and reproductive sinks (DeJong et al., 1987), tree genotype (DeJong and Doyle, 1984; Scorza et al., 1986), and scion–rootstock combination (Glenn and Scorza, 1992). The fruiting process and growth retardants reduce assimilate allocation into vegetative structures (Allan et al., 1993; Chalmers and van den Ende, 1975; Miller and Walsh, 1988). Fruit dry matter production per unit leaf area decreases as leaf area increases (Caruso et al., 1995). Nevertheless, extensive differences in tree growth may not be associated with changes in the relative dry matter allocation within canopy components. Root restriction reduces ultimate tree size with no alteration of dry matter partitioning (Richards and Rowe, 1977).

Peach fruit growth is essentially source limited during Stage I and Stage III of the fruit development period (FDP) (Pavel and DeJong, 1993). Early growth of the fruit and shoot in spring largely depends on assimilate that is produced the previous season and stored in different parts of the tree (Inglese and De Salvador, 1996). Indeed, carbohydrate mobilization from different storage pools is associated with soluble sugar increases and starch content decreases at the commencement of spring growth (Dowler and King, 1966). Alterations in carbohydrate status affect spring regrowth in apple (Abusrewil et al., 1983), and from budset to budbreak, rootstock vigor increases starch content of above-ground components of apple trees (Brown et al., 1985; Stutte et al., 1994). Starch content in above-ground components of French prune is higher in nonbearing than bearing shoots (Ryugo et al., 1977) but depends on the graft combination, being highest with the least vigorous rootstock (Gaudillère et al., 1992). Peach trees treated with growth retardant accumulate more starch than vigorous trees at all stages of growth, particularly at the end of shoot growth (Allan et al., 1993). It is likely that the intense vegetative growth that occurs soon after budbreak in trees grafted on vigorous rootstocks (Allan et al., 1993; Caruso et al., 1995) is associated with an extensive drainage of carbohydrates from storage pools.

Fruiting influences reducing-sugar content in stems of French prune (Ryugo et al., 1977) and rootstock vigor influences sorbitol and sucrose content in above-ground components and in the roots of apple trees, particularly at leaf fall and fruit harvest (Brown et al., 1985; Stutte et al., 1994). To our knowledge, information on the seasonal mobilization of soluble sugars in peach trees is lacking.

In early ripening cultivars, whose FDP last 90 to 120 d, fruit growth occurs concurrently (DeJong et al., 1987) with the major vegetative growth in spring, and vigorous shoot growth, induced by rootstock, may limit assimilate availability to the fruit, eventu-

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Table 1. Productivity, yield efficiency (yield/trunk cross-sectional area), leaf area (LA), leaf area index (LAI), fruit dry mass per unit leaf area (FDM/LA), and total dry mass per unit leaf area (TDM/LA) for 'Flordaprince' peach trees grafted on GF 677 and MrS 2/5 rootstocks.

	Yield/tree (kg)		Yield efficiency ($kg \cdot cm^{-2}$)		LA (m^2)		LAI		FDM/LA ($g \cdot m^{-2}$)		TDM/LA ($g \cdot m^{-2}$)	
Rootstock	1992	1993	1992	1993	1992	1993	1992	1993	1992	1993	1992	1993
GF 677	9.0	16.9	0.28	0.18	27.1	53.1	2.5	4.6	45.6	45.5	134.6	126.8
MrS 2/5	5.0	13.1	0.27	0.24	12.6	28.5	1.2	2.5	54.9	63.5	138.2	140.1
	**	*	NS	NS	**	**	**	**	*	**	NS	NS

$^{\text{NS},*,**}$Nonsignificant or significant at $P < 0.05$ or 0.01, respectively, for differences between the rootstocks.

ally reducing final fruit size and delaying harvest maturity (Allan et al., 1993).

The purposes of this study were to 1) determine how the seasonal pattern of dry matter partitioning is influenced by the vigor of the rootstock, 2) characterize the seasonal pattern of vegetative vs. fruit growth, in relation to vigor, and 3) determine if the seasonal pattern and the extent of the mobilization of stored and soluble carbohydrates within the above-ground components of trees is related to rootstock vigor.

Materials and Methods

Ex vitro GF 677 (*Prunus persica* x *Prunus amygdalus*) and MrS 2/5 (*Prunus cerasifera* open pollination) rootstocks were planted in January 1989 at Sciacca, 50 m above sea level, 37° 30′ N, on a sandy-loam soil (74% sand; 15% clay; 11% silt) with pH 7.8 and low concentration of active $CaCO_3$ (4.5%). Nutrient and organic matter content (1.2%) were within the sufficiency range. The plants, spaced 4.5 × 2.5 m apart (890 plants/ha), were grafted in September 1989 with dormant budwood of the low-chill and early ripening peach (*Prunus persica* L. Batsch) 'Flordaprince'. Grafted trees were trained to a free spindle. The orchard was laid out in a completely randomized block with five replicates and five trees on each rootstock per plot, plus border trees. Trees were irrigated with a microjet system ($100\ mm \cdot year^{-1}$) and annually supplied with 100N–25P–90K ($kg \cdot ha^{-1}$). Fruit were thinned 3 weeks after fruit set, leaving one fruit every 15 cm along the fruiting shoot.

GROWTH AND DRY MATTER PARTITIONING. Trees were sampled destructively throughout two fruiting seasons, from June 1992 to June 1993. Sampling dates were selected to coincide with major developmental stages of tree and fruit growth: fruit harvest (12 June 1992), dormancy (4 Jan. 1993), fruit set (13 Mar. 1993), pit hardening (30 Apr. 1993), and year 2 fruit harvest (15 June 1993). Five trees per scion–rootstock combination were sampled at each date, and above-ground components were fractioned into fruit and leaves (when present), current-season shoots, 1-year-old wood, and >1-year-old wood. The length of current-season shoots and the older wood and their fresh mass were measured immediately after separation. Subsamples were weighed and then dried in a forced-draft oven at 60 °C to constant mass to determine dry mass. Trunk diameter was measured and trunk cross-sectional area (TCA) was calculated. The area of a sample of 500 leaves per tree was measured with a leaf area meter (LI-3100; LI-COR, Lincoln, Nebr.). Total leaf area (LA) per tree was calculated from the ratio of leaf area to leaf dry mass of the sample and the total leaf dry mass of the tree. Leaf area index (LAI orchard), and dry matter production per unit leaf area were then calculated. Fruit yield per tree (kg) was measured and the number of fruits produced by each tree counted at fruit harvest. Yield efficiency was calculated as the ratio of fruit yield per tree to TCA. Individual fresh and dry fruit mass, total soluble solids content (TSS) measured with a digital refractometer (model Pr-1; ATAGO, Tokyo), and total titratable acidity (TTA) were measured on 50 fruit at commercial maturity harvest.

CARBOHYDRATE CONTENT. Starch and soluble sugar content were analyzed on five replicates for each canopy component. Powder samples were extracted three times with boiling 80% ethanol (v/v). The homogenates were centrifuged at 12000 g_n and the ethanolic extract was evaporated in a vacuum (Rotovapor RE 111; Büchi, Switzerland), resolubilized in distilled water, and subjected to enzymatic assay. Glucose, fructose, and sucrose were determined using, respectively, hexokinase, glucose-6-phosphate dehydrogenase, and phosphoglucose isomerase, and after enzymatic inversion to D-glucose and D-fructose by the enzyme beta-fructosidase (Boehringer test combination 716 260). The absorbance was read at 340 nm (UV-2100 spectrophotometer; Shimadzu, Japan). Sorbitol was determined using a sorbitol dehydrogenase assay (Boehringer test combination 670 057) and the absorbance was read at 492 nm. The insoluble pellet resulting from ethanolic extraction was resuspended in HCl and dimethylsulfoxide (DMSO) and incubated for 30 min at 60 °C. After cooling, the pH was adjusted to 4.5 with NaOH under vigorous shaking. The solution was filtered and used for starch determination. Starch was digested for 15 min at 60 °C with amyloglucosidase from *Aspergillus niger* and incubated with glucose assay mix (HK and G6P-DH) at 25 °C. The absorbance was read at 340 nm. Data were analyzed by ANOVA using Systat procedure.

Table 2. Fruit characteristics of 'Flordaprince' peach trees grafted on GF 677 and MrS 2/5 rootstocks.

	Fresh mass (g)		Dry mass (g)		TSS^z (°Brix)		TTA^y (%)	
Rootstock	1992	1993	1992	1993	1992	1993	1992	1993
GF 677	96.3	88.5	13.2	12.6	11.2	13.1	0.9	0.8
MrS 2/5	103.1	99.5	14.3	15.1	12.3	11.8	1.1	1.1
	*	**	*	*	NS	NS	NS	NS

^{z}TSS = total soluble solids.

^{y}TTA = total titratable acidity.

$^{\text{NS},*,**}$Nonsgnificant or significant at $P < 0.05$ or 0.01, respectively, for differences between the rootstocks.

Table 3. Evolution of carbohydrate content, dry mass basis, (mg·g^{-1}) in fruit of 'Flordaprince' peach trees grafted on GF 677 and MrS 2/5 rootstocks (data are mean ± SE).

Developmental	Fruit set		Pit hardening		Fruit harvest	
stage/rootstock	GF 677	MrS 2/5	GF 677	MrS 2/5	GF 677	MrS 2/5
Starch	0.6 ± 0.02	0.7 ± 0.03	1.2 ± 0.02	1.9 ± 0.07	0.0	0.0
Fructose	20.7 ± 0.13	12.4 ± 0.21	95.2 ± 1.7	70.3 ± 1.5	98.3 ± 2.4	88.1 ± 4.0
Glucose	6.4 ± 0.25	6.3 ± 0.09	32.0 ± 1.9	44.7 ± 3.3	86.5 ± 2.7	85.6 ± 1.1
Sucrose	0.9 ± 0.02	1.2 ± 0.06	1.0 ± 0.12	1.1 ± 0.14	542.1 ± 15.6	572.0 ± 15.3
Sorbitol	9.5 ± 0.17	9.7 ± 0.07	11.4 ± 0.72	9.5 ± 0.46	12.6 ± 1.4	14.8 ± 1.4

Results

Growth and productivity. GF 677 trees had ≈80% and ≈35% higher yields and ≈115% and ≈85% greater LA than MrS 2/5 trees in 1992 and 1993, respectively. Since ground area allotted for each tree was the same for the two rootstocks, LAI increased in proportion to LA (Table 1). Increases in yield and LA between 1992 and 1993 were ≈88% and ≈95% in GF 677 and ≈148% and ≈125% in MrS 2/5 trees (Table 1). Trees on GF 677 were almost twice the size of MrS 2/5 trees, whereas yields did not increase in proportion to tree size. Indeed, yield efficiency was not affected by the rootstock and decreased in both rootstocks in 1993 as LA increased. Fruit dry matter produced per unit leaf area significantly decreased with the vigor of the rootstock, whereas total dry matter per leaf area was not affected by the rootstock (Table 1).

Higher yield of GF 677 trees depended on fruit number per tree rather than individual fresh mass (Table 2). Indeed, fresh and dry fruit mass were significantly higher for MrS 2/5 than GF 677 trees, but neither TSS nor TTA was affected by rootstock vigor (Table 2). From fruit set to pit hardening (≈50 d after fruit set), fruit accumulated reducing sugars, particularly fructose; whereas, during Stage III of the fruit development period, sucrose content increased abruptly, representing ≈75% of total carbohydrate content in the flesh at fruit harvest (Table 3). Fruit starch content was negligible throughout the FDP.

At pit hardening, LA was more than three times higher in GF 677 than MrS 2/5 trees. At this stage, LA already had reached 35% of its harvest value in GF 677 trees and ≈25% in MrS 2/5 trees (Fig. 1), and fruit dry mass-to-leaf area ratio was 10 ± 1.2 g·m^{-2} in GF 677 trees and 26 ± 2.4 g·m^{-2} in MrS 2/5 trees.

Dry matter partitioning. Rootstock affected dry matter accumulation into above-ground components of the peach trees (Table 4). At the harvest sampling date in 1992 and 1993, trees on GF 677 accumulated about twice as much dry matter as trees on MrS 2/5. Large differences occurred throughout the sampling dates for the dry mass of perennial components (>1-year wood) as a result of the faster development induced by the vigorous GF 677 rootstock. By the harvest sampling date in 1992, dry matter allocated into the 1-year wood was almost three times higher in GF 677 than MrS 2/5. A lighter winter and summer pruning and the development of the structure of MrS 2/5 trees accounted for the reduction of such differences in 1993, when dry matter allocated in 1-year wood of GF 677 trees was 1.5 times higher than in MrS 2/5 (Table 4). The ratio between perennial components and 1-year old wood ranged from 2.5 and 2.2 at the harvest sampling date in 1992 to 3.6 and 3.0 at harvest sampling date in 1993 for GF 677 and MrS 2/5 trees, respectively. At the harvest sampling date in 1993, the ratio of annual dry mass (shoots, leaves, and fruit) produced per unit leaf area was 0.13 and 0.15 kg·m^{-2} leaf area for GF 677 and MrS 2/5 trees, respectively.

Rootstock affected dry matter partitioning within above-ground components, and, by harvest sampling dates, trees on GF 677 partitioned more dry matter to the structural components and less to the fruit than MrS 2/5. Harvest index (HI), calculated as the ratio between dry matter that was allocated to the fruit vs. dry matter allocated to the current season's growth (shoots, leaves and fruits), was 34 and 36 for GF 677 and 39 and 45 for MrS 2/5 trees by the harvest sampling date in 1992 and 1993. By the harvest sampling date in 1993, MrS 2/5 trees had accumulated 50% less dry matter into the current season's vegetative growth (shoots and leaves) and 25% less dry matter into fruit than GF 677 trees (Table 4). Rootstock affected the seasonal dry matter partitioning within vegetative and fruit growth (Fig. 2). By pit hardening, when fruit thinning already had been applied, trees on GF 677 and MrS 2/5 allocated about the same amount of dry matter to the fruit (Table 4). Despite this similarity, the dry matter allocated to the fruit represented 9.5% and 23.4% of the current season's growth for GF 677 and MrS 2/5 respectively, because leafing and shoot growth were significantly higher in GF 677 trees (Fig. 2). The vegetative-to-fruit dry mass ratio by pit hardening was 3:1 for MrS 2/5 and 9:1 for GF 677 trees (Table 4).

Carbohydrate levels. Starch content was greater in woody tissues (Fig. 3) of peach trees than in leaves and shoots (Fig. 4). Starch content was highest during dormancy, declined sharply during the early stages of budburst, and continued to decrease until fruit harvest (Fig. 3). Trees on GF 677 had the highest values in winter and the lowest during pit hardening and the following rapid

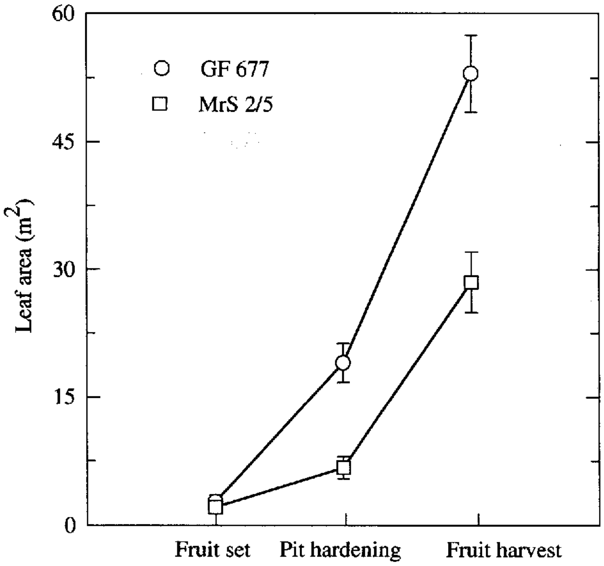

Fig. 1. Leaf area development throughout 1993 growing season, at fruit set (13 Mar.), pit hardening (30 Apr.), and fruit harvest (15 June) for 'Flordaprince' peach trees grafted on GF 677 (○) and MrS 2/5 (□) rootstocks. SE bars are visible when larger than symbol.

Table 4. Seasonal variation of dry matter content in above-ground components of 'Flordaprince' peach trees grafted on GF 677 and MrS 2/5 rootstocks (data are mean ± SE).

Rootstock	Harvest 1992 (g)	Dormancy 1993 (g)	Fruit set 1993 (g)	Pit hardening 1993 (g)	Harvest 1993 (g)
GF 677					
>1-year-old wood	2237 ± 341	3560 ± 384.5	3818 ± 631	3951 ± 237	5946 ± 414.7
1-year-old wood	907.5 ± 33	1301.3 ± 134.5	1712 ± 304	1903 ± 140	1658 ± 203.7
Shoots	752.2 ± 34	---	19 ± 0.5	317.6 ± 11.6	1051 ± 81.9
Leaves	1660 ± 213	---	242 ± 16.3	1458.3 ± 71.3	3268 ± 225
Fruit	1236.3 ± 44	---	19.6 ± 1.9	187.9 ± 3.5	2413 ± 153.1
Total	6793 ± 275	4861.3 ± 212.1	5793.5 ± 296	7817.8 ± 399.2	14336 ± 599.3
MrS 2/5					
>1-year-old wood	835 ± 39	2006.1 ± 117.2	2616 ± 182.5	3492 ± 235	3188 ± 491.2
1-year-old wood	373 ± 34	855.2 ± 83.4	1088 ± 90.2	960.8 ± 71.1	1077 ± 100.8
Shoots	284 ± 29	---	17 ± 3.9	58.6 ± 4.9	420 ± 56.6
Leaves	766 ± 116	---	134.5 ± 9.9	512.5 ± 13.9	1764 ± 206.4
Fruit	692 ± 84	---	13.9 ± 2.1	174.4 ± 14.5	1809 ± 116.1
Total	2950 ± 125	2861.3 ± 355	3869.4 ± 154.1	5198.3 ± 315.1	8258 ± 396

cell enlargement period, when most of seasonal leaf area and shoot development occurred (Fig. 1, Table 4). Rootstock had a significant effect on starch content in woody tissues and, at fruit set, starch content in >1-year wood and 1-year wood was 57% and 44% lower than during dormancy for GF 677 and MrS 2/5 trees, respectively. Starch content in >1-year wood MrS 2/5 trees was relatively constant throughout the FDP. Starch content in the components of the current season's vegetative growth was highest at fruit set and decreased during FDP, with no effect of the rootstock and inconsistent differences between leaves and shoots (Fig. 4).

The sum of glucose, fructose, sorbitol, and sucrose was higher in the current season's vegetative growth than in the woody plant parts throughout the season (Figs. 5 and 6). Differences were greatest in sorbitol and fructose content, whereas sucrose showed the lowest values, with little variation between canopy components (Fig. 5). Concentrations of soluble sugars in the shoots peaked at fruit set and decreased with active shoot and fruit growth, but were relatively constant throughout the season in the older wood (Fig. 6). Sorbitol concentration was higher than fructose and glucose concentrations throughout the season in the shoots (Fig. 7) and leaves (Fig. 8). Sorbitol and glucose concentrations in the shoots decreased linearly during the FDP, whereas fructose did not show any change from pit hardening to fruit harvest (Fig. 7). Sorbitol content slowly decreased during the same period, whereas fructose and glucose content at fruit harvest was ≈70% lower than at fruit set (Fig. 8).

Discussion

Rootstock vigor affected tree growth, productivity, and fruit size in the low-chill, early ripening 'Flordaprince' peach . Four years after budding, trees on GF 677 were twice the size of those on the weaker MrS 2/5 rootstock, in terms of leaf area and total above-ground dry mass, with LA and LAI values similar to those reported for 9-year-old nectarine trees grafted on P.S. B 2 (*Prunus persica*), and trained to free spindle (Loreti et al., 1994). However, differences in yield were not as great as those in tree growth. Trees on GF 677 produced 15 t·ha^{-1} of fruit, whereas trees on MrS 2/5 gave only 25% lower yields (11.5 t·ha^{-1}).

Previous findings indicate that fruit dry mass produced per unit leaf area decreases as leaf area increases (Caruso et al., 1995). Reasons for this could include increased self-shading in the canopy and decreased partitioning. In this study, reduced vegetative growth during FDP resulted in higher partitioning of dry matter to the fruit compared to above-ground vegetative structures in trees grafted onto MrS 2/5, while GF 677 trees were less efficient than MrS 2/5 in terms of HI. Chalmers and van den Ende (1975) found that 60% of annual dry mass was distributed to the fruit, for a tree size corresponding to 9-year-old trees, but they argued that conversion of dry mass to the fruit may change with yielding characteristics, particularly for early yielding intensive orchards. HI values found in our study are slightly lower than those reported on 'Loring' 8-year-old peach trees on Halford rootstock (Miller and Walsh, 1988), where the total amount of dry mass allocated to the fruit was three times greater than in our study. The lower HIs we found might be also related to the fruit size potential, which is inherently lower in early ripening peach cultivars (DeJong et al., 1987).

Total above-ground tree dry mass at harvest (≈100 d after spring

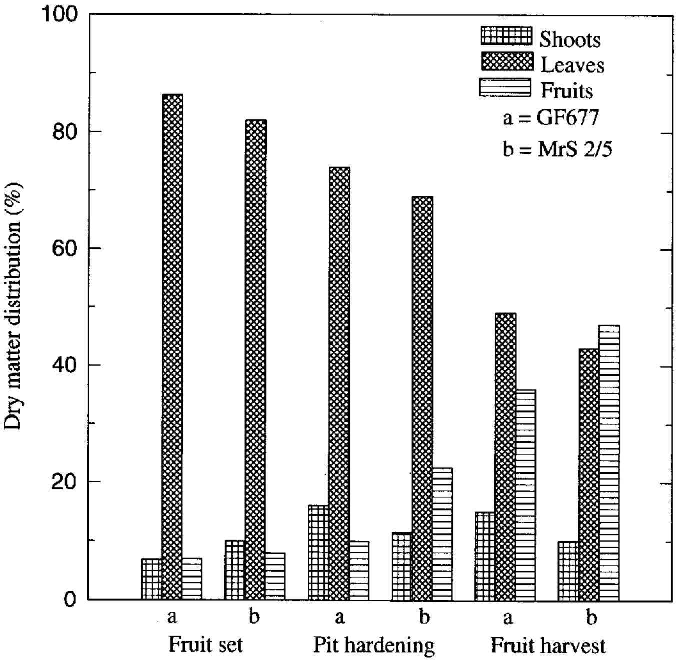

Fig. 2. Seasonal dry matter distribution into current season's growth components of 'Flordaprince' peach trees grafted on GF 677 and MrS 2/5 rootstocks.

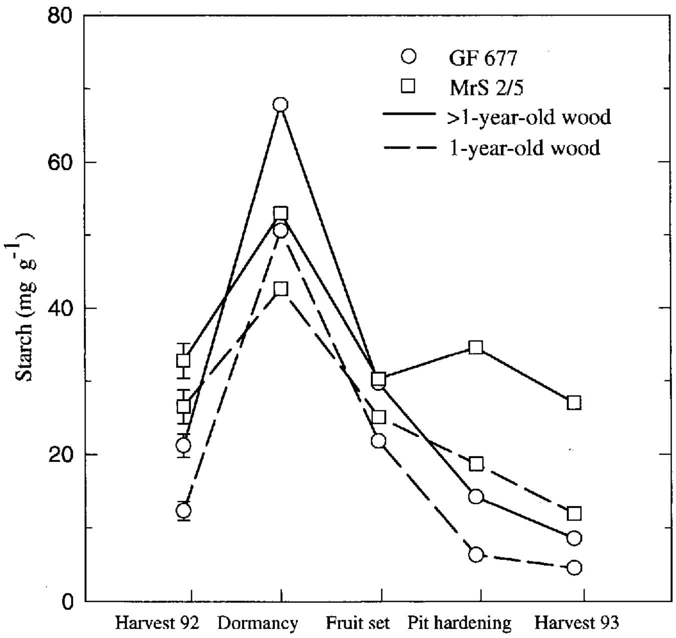

Fig. 3. Evolution of starch concentration, dry mass basis, at harvest 1992 (12 June), during dormancy (4 Jan. 1993), and at fruit set (13 Mar.), pit hardening (30 Apr.), and fruit harvest (15 June) in >1-year-old wood and 1-year-old wood of 'Flordaprince' peach trees grafted on GF 677 (○) and MrS 2/5 (□) rootstocks. SE bars are visible when larger than symbol.

burst) was 2.1 and 2.5 times greater than at the beginning of the season for MrS 2/5 and GF 677 trees. Fruit contribution to annual dry mass gain was 43% in MrS 2/5 trees and 28% in GF 677 trees, whereas secondary growth in perennial components accounted for 12% and 25%, respectively. To summarize, trees on GF 677 allocated 20% more dry matter to the fruit, being twice the size in terms of leaf area and total above-ground dry matter and having ≈40% more fruit than MrS 2/5 trees. Consistent with previous findings (Chalmers and van den Ende, 1975), the proportion of dry matter that was allocated to the current season's vegetative growth did not change with the vigor of the rootstock, being ≈35% for the leaves and ≈10% for the shoots, revealing a tight balance between tree development, leafing, and shoot growth.

At the end of the season we excavated three plants per rootstock to analyze the development of the root system. The roots of GF 677 explored a much wider area than those of MrS 2/5, and the dry mass of MrS 2/5 roots was only 25% as much as GF 677 roots. The apparent reason for this difference was the predominance of primary, thick, suberized roots in GF 677 rootstock, contrasted to thin, absorbing roots attached directly to the trunk-base or into short primary roots in the root system of MrS 2/5. The dry mass ratio of above-ground to below-ground was 4:1 in MrS 2/5 trees and 2:1 in GF 677 trees.

Final fruit size of early ripening peaches depends on fruit growth rate during the early stages of FDP (Caruso et al., 1993) and is closely associated with fruit mass at the beginning of the cell enlargement period (Stage III) (DeJong et al., 1987). At fruit set, dry mass of individual fruit ranged greatly according to the phenology of bloom, with no significant differences between the rootstocks (±5%). Individual fruit dry mass at pit hardening was 32% lower in GF 677 (0.98 ± 0.02 g) than MrS 2/5 trees (1.45 ± 0.03 g), possibly as a result of competitive shoot growth, as indicated by the much higher leaf area to fruit dry weight ratio, and higher inter-fruit competition at earliest stages of growth in GF 677 trees, which had 40% more fruit than MrS 2/5. Fruit size at harvest was 17% higher in the less-vigorous rootstock. Fruit size was in the range reported by Sherman et al. (1984) and Allan et al. (1993) for 'Flordaprince' fruit. However, rootstock vigor does not always lead to a reduction of fruit size, provided there is proper orchard management. Vigorous rootstocks require more precise timing of summer pruning and earlier thinning than standard or weak rootstocks (Caruso et al., 1995, 1996). With proper management, however, the earlier leafing and faster leaf development of these vigorous rootstocks may increase the leaf area-to-fruit ratio during the early stages of fruit growth, potentially increasing fruit growth rate.

As reported for French prune (Gaudillère et al., 1992), the effect of the rootstock on starch concentration in above-ground components depended on the time of the season. GF 677 trees had twice the storage carbohydrate than the less-vigorous MrS 2/5 trees during dormancy, but a lower concentration throughout the FDP. The higher seasonal drainage of reserves in the above-ground components of GF 677 trees was the result of a greater demand for assimilates, particularly during early stages (Stage I) of the FDP. During this period, leaf area is still poorly developed, distribution of photoassimilate from apical shoots is limited (Corelli Grappadelli et al., 1996), and fruit and shoot growth largely depends on reserves (Allan et al., 1993). Perennial components were the largest pool for starch storage in the aerial parts, representing 75% of total starch during dormancy and 90% at fruit harvest.

During dormancy, the total amount of starch was twice as great in GF 677 as MrS 2/5 trees. Despite the different dry mass accumulation at harvest, no differences between the rootstocks in total starch were found during fruit growth. Evidently, GF 677 trees were able to fully replenish the carbohydrate storage pools after the grand season of growth that, for early ripening cultivars coincides with the FDP.

The depletion of starch at fruit set was accompanied by high concentrations of sorbitol and reducing sugars in the vegetative growth for the current season. For soluble sugars, differences attributable to the rootstock were inconsistent. Sorbitol was the most abundant carbohydrate in the leaves and in the shoots, being

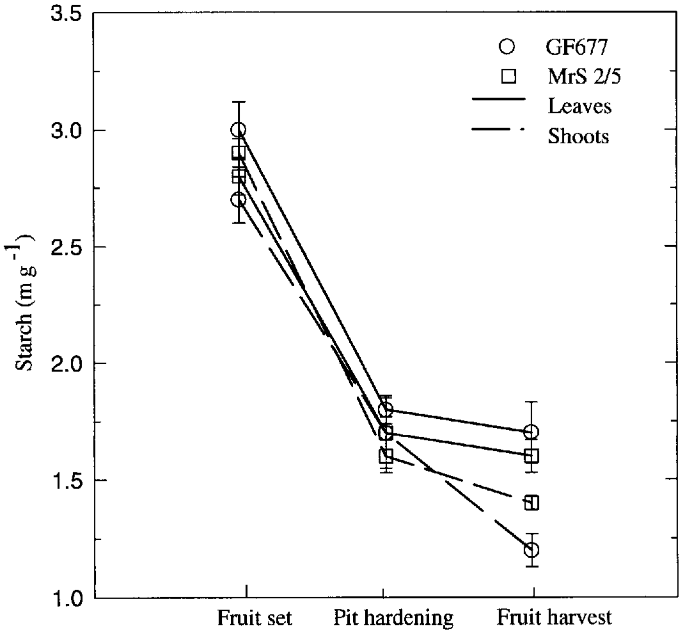

Fig. 4. Seasonal evolution of starch concentration, dry mass basis, in leaves and shoots of 'Flordaprince' peach trees grafted on on GF 677 (○) and MrS 2/5 (□) rootstocks. SE bars are visible when larger than symbol.

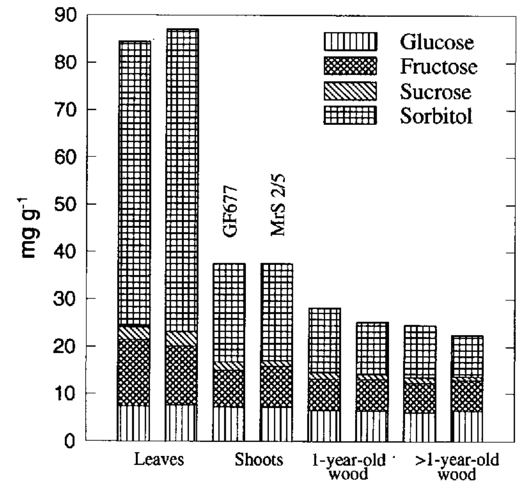

Fig. 5. Soluble sugars concentration, dry mass basis, in above-ground components of 'Flordaprince' peach trees grafted on GF 677 (○) and MrS 2/5 (□) rootstocks, measured at harvest sampling date (12 June 1992).

the transport sugar of the Rosaceae family (Webb and Burley, 1962). Sorbitol seasonal concentration was relatively constant in the leaves, while reducing sugars showed a very sharp decrease in the leaves and shoots from fruit set to fruit harvest. This agrees with previous findings indicating an inverse relationship between active growth and soluble sugar content in above-ground components and in the roots (Brown et al., 1985; Gaudillère et al., 1992; Stutte et al., 1994).

Trees on GF 677 and MrS 2/5 rootstocks had a different balance between vegetative growth and fruiting that resulted in smaller fruit in the most-vigorous trees. The vigor of the rootstock dictates that different orchard management strategies are needed to reduce vegetative growth in vigorous trees, particularly during the early stages of fruit growth.

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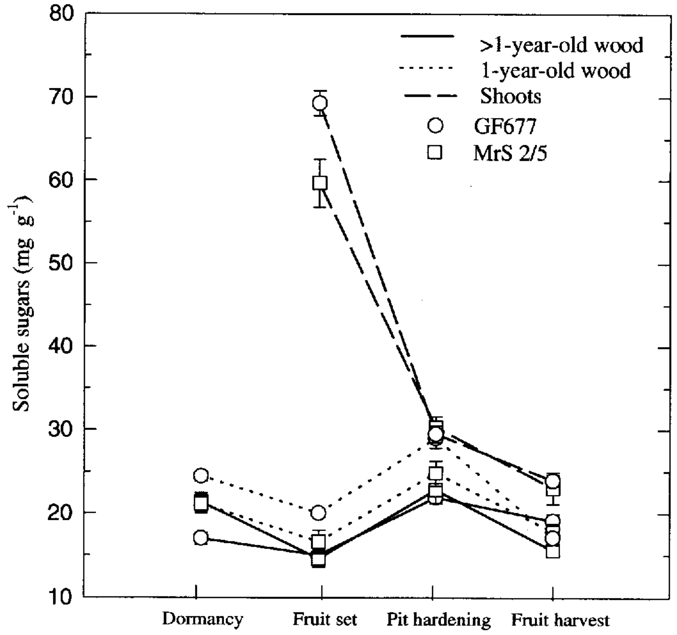

Fig. 6 Seasonal evolution of soluble sugars concentration, dry mass basis, in >1-year-old wood, 1-year-old wood, and current season's shoots of 'Flordaprince' peach trees grafted on GF 677 (○) and MrS 2/5 (□) rootstocks. SE bars are visible when larger than symbol.

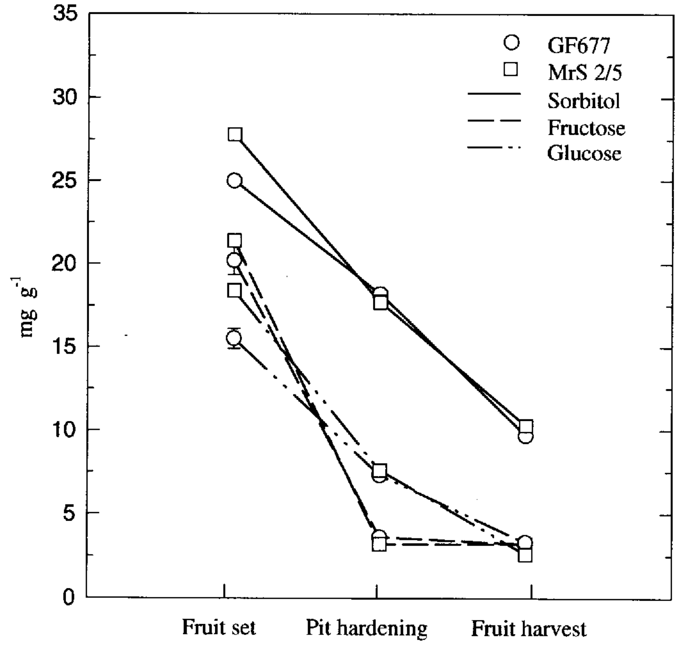

Fig. 7. Seasonal evolution of sorbitol, fructose, and glucose concentration, dry mass basis, in the current season's shoots of 'Flordaprince' peach trees grafted on GF 677 (○) and MrS 2/5 (□) rootstocks. SE bars are visible when larger than symbol.

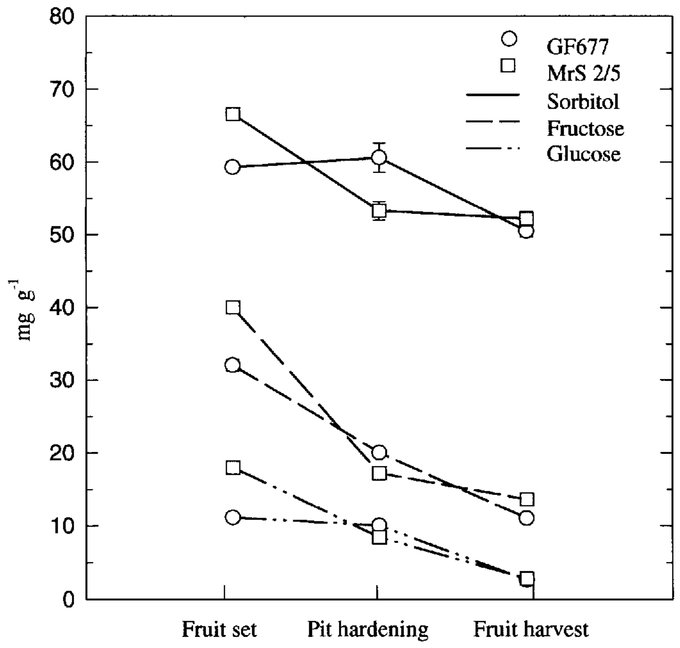

Fig. 8. Seasonal evolution of sorbitol, fructose, and glucose concentration, dry mass basis, in the leaves of 'Flordaprince' peach trees grafted on GF 677 (○) and MrS 2/5 (❑) rootstocks. SE bars are visible when larger than symbol.

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