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Comparison of Ten Peach Rootstocks Performance Grafted with 'Redhaven'.

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Summary

The selection of appropriate rootstock plays an important role in designing a new orchard or in renewing an old one. The identification of rootstocks that cope well in replant soil is therefore necessary to maintain similar production capacity and fruit quality of peach orchards. We have evaluated ten peach rootstocks planted in virgin and replant soil by monitoring tree vigour, yield efficiency, effect on fruit maturity and quality parameters, through two growing seasons. Maturation was affected by rootstock, and Julior appeared to delay fruit maturity. All rootstocks produced higher quality fruit in virgin soil, which was reflected in higher contents of sugars compared to replant soil. Barrier 1, GF 677 and peach seedlings adapted best to virgin soil conditions. For replant conditions, Adesoto, Tetra and Penta rootstocks showed the greatest potential.

Key words. *Prunus persica* – HPLC – sugars – organic acids

Introduction

Prunus rootstock can dramatically influence the orchard performance of peach cultivars (Layne 1994); therefore, choosing of the optimal rootstock must be considered when designing a new peach orchard or replanting an old one. Scion growth and development, scion physiology as well as orchard design and management are all factors affected by rootstock (Layne 1994) and vary greatly among the numerous peach rootstocks available. Besides *Prunus persica* (L.) Batsch a variety of stone fruit species can be used as peach rootstock; plum and its hybrids (Layne 1994; Hudina et al. 2006) as well as almond and its hybrids (Hudina et al. 2006; Massai and Loreti 2004). Adaptation to different pedo-climatic conditions has become an increasingly important aspect of rootstock selection and has proven to be largely dependant on rootstock's genetic origin (Layne 1994; Iglesias et al. 2004; Giorgi et al. 2005). One of the problems related to pedo-climatic conditions is soil sickness, in replant conditions (Massai and Loreti 2004). The denomination of "soil sickness" indicates, in agriculture, a condition of progressive soil inhospitality to frequent return of a single crop. The decline of productivity which follows is generally confined to the reiterated species, affecting less other plants, mostly if botanically unrelated (Zucconi 1993). Savory (1969) and Zucconi (1993) described replanting problems in fruit trees with specific replant diseases and non-specific replant diseases. The factors responsible for the latter are toxic plant products (Zucconi et al. 1984; Neri et al. 2002; Giorgi et al. 2008), nematodes, unbalanced soil nutrition, poor soil structure and drainage well as low or high pH levels (Mai and Abawi 1978). Specific replant diseases are characterized by poor growth of trees planted in soil in which the same species or another species of the same genus has been grown (Savory 1969). The accumulation of residues from a sole crop disrupts the humification process, inducing odd decompositions that delay stabilization and release toxic metabolites (Zucconi 1993). These, in turn, may induce specific allelopathic effects (dispathy) accounting for 'soil sickness' (Patrick et al. 1964; Elliot and Papendick 1986; Zucconi et al. 1987). Root absorption, in particular, may be hindered by these toxins (Zucconi 1993) ensuing dystrophies and root die-back (Giorgi et al. 2008).

Plums will thrive normally when planted after any fruit species, except peach (Utkhede and Tomas 1988). They also reported that peach can be planted after any fruit species or grapevine crop. However, Gur and Cohen (1988) have found retarded growth of peach trees when planted after originating trees of *P. persica*.

Beckman and Okie (2002) demonstrated that different rootstocks influence variations in blooming date as well as in the duration of fruit development. Reighard et al. (2008) reported 4 to 5 days variations in maturity date among several rootstocks tested. Fruit firmness is one of the most important parameters for determining fruit maturity (Bernhard and Grasselly 1981) since fruit in general become softer with progressing maturity. Ground colour measurements have also been proven to be a parameter significantly dependant on fruit maturity. According to Delwiche and Baumgardner (1983) the a* value increases with progressing maturity as fruit becomes redder.

Fruit quality and nutritional attributes are also factors, greatly influenced by the rootstock (Hudina et al. 2006; Giorgi et al. 2005). As early as 1982, Kader et al. defined fruit quality firstly by chemical characteristics and secondly by the physical characteristics that make a product appeal-

ing and acceptable to the consumer. Efforts should be made by researchers and breeders to provide growers with new rootstocks and with information on rootstock/cultivar combinations, which fulfil both grower's needs and consumer demand.

Our experiment has been designed to evaluate ten promising rootstocks in virgin soil and in replant conditions by monitoring the fruit quality characteristics of 'Redhaven'.

Material and Methods

Plant material

Our experiment was conducted in an orchard at the Fruit Growing Centre in Bilje near Nova Gorica (N 450 53.528; E 0130 38.606), Slovenia, in two consecutive years, 2008 and 2009. Some annual data have been published by Orazem et al. (2011) and are included herein for the comparison purposes of the two soil types. Two fields were selected to set up the experiment. The first field with replant soil previously supported two generations of peach orchard with new generation being planted every 15 years. For the first generation, peach seedling was used as a rootstock, while for the second generation GF 677 rootstock was selected. The second field with virgin soil had previously never been planted with trees of the *Prunus* genus. The soil in both orchards was silt–loam (64 % silt, 21 % clay and 15 % sand). The experiment included combinations of 'Redhaven' scions grafted on ten rootstocks: Barrier 1 (*P. persica* × *Prunus davidiana* L.), Cadaman (*Prunus persica* L. × *Prunus davidiana* L.), Monegro (*P. amygdalus* Batsch. × *P. persica*), GF 677 (*P. amygdalus* × *P. persica*), Adesoto (*Prunus insititia* L.), Julior (*Prunus insitiata* L. × *Prunus domestica* L.), Penta (*P. domestica*), Tetra (*Prunus domestica* L.), MrS 2/5 (*Prunus cerasifera* Ehr.), peach seedling (*P. persica*). 'Redhaven' is a yellow-pulp peach cultivar and represents the standard cultivar in Slovenia.

The rootstocks were planted in a permanent place in spring 2005, with 4 × 2 m tree spacing. The T budding was performed in August 2005. On each field, every scion/rootstock combination had 12 replications that were randomly distributed in groups of three in a randomized block design. The trees were trained to a free spindle, and the whole orchard was managed according to standard integrated pest management.

In the spring of 2008 and 2009, the circumferences of individual trees were measured 15 cm above the graft union to determine the tree's vigour. Peaches were harvested four times, three days apart. At each picking time, all ripe fruit from each tree were harvested. The fruit were weighted and yield efficiency (kg cm^{-2}) was calculated by summing up fruit weight for each tree.

The fruits for the analysis were randomly collected at first harvest picking in 2008 and 2009. In 2008, fruit were harvested 121 days after full bloom (DAFB), while in 2009 they were harvested 112 DAFB. From each scion/rootstock combination, 15 fruits from each field were picked at 'Redhaven' ripeness and transported to the laboratory facilities. All quality analysis and extractions were made at room temperature (24 °C). Each fruit was weighted on a precision scale a 0.01 g confidence level. Ground colour was measured with a Minolta portable colorimeter (Model CR 300 Croma Minolta camera Co.; Osaka, Japan), and a* values (−60 green, +60 red) were noted. Fruit skin was removed on four sides of each fruit prior to measuring fruit firmness using a digital penetrometer with 8 mm tip. A digital refractometer model WM-7 (Atago; Tokyo, Japan) was used to measure soluble solids content. Immediately after these measurements, peaches were randomly grouped into 5 groups (5 repetitions) of 3 fruit. Each fruit was stoned and cut into pieces. For each group (3 unpeeled fruit) the extraction of sugars and organic acids was performed.

Extraction of sugars and organic acids

The same method of extraction was used to extract both sugars and organic acids. Ten grams of unpeeled fruit was brought to a total volume of 40 ml using twice distilled water. Each sample was homogenized with T-25 Ultra-Turrax (IKA® – Labortechnik; Staufen, Germany), and left to extract for half an hour at room temperature (24 °C). Samples were centrifuged at 12857 g for 7 minutes at 5 °C (Eppendorf 5810 R Centrifuge; Hamburg, Germany), and the supernatant was filtered through a 0.45 µm cellulose filter (Macherey-Nagel; Düren, Germany). The content of individual sugars (sucrose, glucose, fructose and sorbitol) was determined by HPLC using refractive index detection (Thermo Separation Products; Waltham, MA). The chromatographic system included a Razex RCM – monosaccharide column (300 × 7.8 mm; Phenomenex; Torrance, CA), which was kept at 60 °C. The mobile phase (isocratic system) was twice distilled water. The flow rate of the mobile phase was 0.6 ml min^{-1}. A refractive index (RI) detector was used (Thermo Scientific, Waltham, MA) to detect our compounds by the method described by Sturm et al. (2003). Individual sugars were identified by comparison of the retention time of each peak with those of corresponding standard and the concentration was calculated using an external standard. Total sugar content was calculated by summing up individual sugars contents and expressed in g kg^{-1}.

The same equipment was used for organic acid (malic acid, citric acid, shikimic acid and fumaric acid) content analysis with some minor modifications. A different column (HPX 87H, 300 × 7.8 mm; Bio-Rad; CA, USA) was kept at 60 °C. The mobile phase (isocratic system) was a 4 mM H_2SO_4 aqueous solution. The flow rate of the mobile phase was 0.6 ml min^{-1}. An ultra violet (UV) detector, set at 210 nm (Knauer; Berlin, Germany) was used for identification and quantification. The identification was made by comparison of the retention time for each peak with those for corresponding standard, and the concentration was calculated using an external standard. The method described by Sturm et al. (2003) was utilized. Total organic acids content was calculated by summing up individual organic acids contents and expressed in g kg^{-1}.

Statistics

The data was analyzed using the Statgraphics Centurion XV (Statgraphics, Herdon, VA) program. One-way ANOVA was used to determine the significance of soil type on yield efficiency and on various quality parameters. Differences between the two soil types were tested with the LSD test at significance level of 0.05. Multivariate statistical analysis (hierarchical cluster analysis, discriminate

analysis and classification) was conducted in order to interpret the differences in fruit maturity between the rootstocks for each soil type on the basis of fruit firmness and ground colour (a* value).

Results and Discussion

Rootstock vigour

The measurement of the circumference enabled us to rank our rootstocks according to their vigour (Table 1). We compared each rootstock with GF 677, which is currently used in the majority of peach orchards in Slovenia and is annotated as vigorous rootstock (Giorgi et al. 2005). In 2008, we found Penta, MrS 2/5 and Tetra to cause the weakest tree vigour in virgin soil reaching 69, 74 and 75 % of GF 677 vigour, respectively. Remorini et al. (2008) also found MrS 2/5 to induce weak growth of 'Flavorchrest' cultivar. We found semi-vigorous growth to be characteristic of peach seedling, Julior, Cadaman and Adesoto rootstocks, reaching 78, 79, 81 and 83 % of GF 677 vigour, respectively. Monegro, GF 677 and Barrier 1 rootstocks affected the highest vigour. In 2009, most rootstocks in virgin soil had managed to offset the smaller circumference of 2008, since none of the rootstocks exhibited a level of vigour below 78 % (MrS 2/5) of GF 677's vigour.

In replant soil, a somewhat different ranking according to vigour was found (Table 1). In general, smaller differences were found among the rootstocks. In 2008, GF 677 caused semi-vigorous growth, while in 2009 it had overcome the deficit and had one of the largest circumferences among the rootstocks tested, indicating vigorous growth. Massai and Loreti (2004) also reported the most vigorous growth for trees grafted on GF 677 rootstocks in replant soil. Tetra, Penta and peach seedling rootstocks were found to cause the weakest vigour, reaching 91, 91 and 93 % of GF 677 vigour in 2008, and 85, 84 and 81 % of GF 677 in 2009. Peach seedling, however, had the smallest circumference increase among all the rootstocks tested and was found to be the weakest in 2009. In contrast to virgin soil, MrS 2/5 caused semi-vigorous growth reaching 98 % of GF 677 vigour in 2008. Julior and Adesoto were also annotated as semi vigorous rootstocks. Massai and Loreti (2004) reported semi-vigorous growth to be characteristic of plum clone hybrids (Adesoto, Julior, MrS 2/5, Penta) in replant soil, which is consistent with our results. In contrast to virgin soil, Cadaman rootstock caused vigorous growth, in 2008 and 2009. Barrier 1 and Monegro had a similar effect on vigour in both soil type conditions. This is in accordance with Massai and Loreti (2004) who also reported Barrier 1 and Cadaman to cause similarly vigorous growth in comparison to GF 677 in replant conditions.

Table 1. Comparison of 'Redhaven' tree vigour grafted on ten rootstocks in virgin and replant soils in 2008 and 2009.

Rootstock	Soil type	Circumference (% compared to standard rootstock GF 677)	
		2008	2009
GF 677	Virgin soil	100	100
	Replant soil	100	100
Barrier 1	Virgin soil	107	97
	Replant soil	111	101
Cadaman	Virgin soil	81	86
	Replant soil	119	101
Monegro	Virgin soil	93	95
	Replant soil	107	109
Adesoto	Virgin soil	83	86
	Replant soil	102	93
Julior	Virgin soil	79	90
	Replant soil	96	87
Penta	Virgin soil	69	75
	Replant soil	91	84
Tetra	Virgin soil	75	84
	Replant soil	91	85
MrS 2/5	Virgin soil	74	78
	Replant soil	98	91
Peach seedling	Virgin soil	78	84
	Replant soil	93	81

Rootstocks and soil type affecting 'Redhaven' yield efficiency and quality indices

In order to determine natural crop load of our trees, yield efficiency was calculated on basis of trunk circumference and total yield. In 2008 yield efficiency was less uniform compared to 2009, since 2008 was the first bearing season (Table 2). In 2008, significant differences were found for several rootstocks when growing in different soil types. We found significantly higher yield efficiency of Adesoto, Penta and MrS 2/5 grafted trees when growing in replant soil. Only for GF 677 grafted trees higher yield efficiency was recorded in virgin soil. Barrier 1, Cadaman, Monegro, Julior, Tetra and peach rootstocks had similar yield efficiency in both soil types. In 2009, we found that yield efficiency was similar in both soil types for all scion/rootstock combination except for Tetra.

In 2008 and 2009, significant differences in fruit weight and soluble solids content were observed among rootstocks tested. This is in accordance with the results obtained by Remorini et al. (2008). In 2008 and 2009, in general, two soil types did not affect fruit weight for most of the rootstocks despite differences in yield efficiency. In 2008, GF 677 rootstock produced lighter fruit in replant soil, despite higher yield efficiency in virgin soil. Average fruit weight of fruit harvested in 2008 from Barrier 1 grafted trees was considerably lower, which was caused by higher yield efficiency in comparison with other rootstocks. In 2009, no differences in fruit weight were recorded when comparing rootstock in each of the soil type.

In 2008, soil type had no effect on soluble solids content for fruit harvested from GF 677, Adesoto and Tetra rootstock. We found that 'Redhaven' fruit from most rootstocks growing in replant soil had lower soluble solids contents. This is apparent even in the case of MrS 2/5 and peach seedling rootstock where lower values of soluble solids contents were measured despite similar fruit maturity stage. In 2009, several rootstocks (Barrier 1, Monegro, Adesoto, Penta and Tetra) were not affected by soil type in terms of soluble solids content. For other root-

Table 2. Comparison of yield efficiency, fruit weight and soluble solids of 'Redhaven' fruit from ten rootstocks in virgin and replant soils in 2008 and 2009.

Rootstock	Soil type	Yield efficiency (kg cm^{-2})	Weight (g)	Soluble solids (%)	Yield efficiency (kg cm^{-2})	Weight (g)	Soluble solids (%)
		2008			2009		
Barrier 1	Virgin soil	1.16 ± 0.05 NS	120.3 ± 3.7 NS	10.0 ± 0.21 b	1.02 ± 0.05 NS	188.7 ± 7.6 NS	10.7 ± 0.36 NS
	Replant soil	0.98 ± 0.09 NS	124.0 ± 4.4 NS	9.2 ± 0.29 a	1.12 ± 0.08 NS	174.8 ± 5.3 NS	9.8 ± 0.29 NS
Cadaman	Virgin soil	0.61 ± 0.05 NS	145.0 ± 5.1 NS	10.1 ± 0.20 b	1.36 ± 0.06 NS	163.5 ± 4.6 NS	10.1 ± 0.29 b
	Replant soil	0.83 ± 0.07 NS	144.0 ± 5.7 NS	9.0 ± 0.22 a	1.54 ± 0.08 NS	173.5 ± 6.6 NS	8.9 ± 0.29 a
Monegro	Virgin soil	0.45 ± 0.06 NS	154.9 ± 5.0 NS	10.8 ± 0.22 b	1.03 ± 0.05 NS	173.0 ± 3.3 NS	9.9 ± 0.32 NS
	Replant soil	0.37 ± 0.08 NS	141.0 ± 4.4 NS	8.7 ± 0.17 a	1.01 ± 0.01 NS	171.7 ± 3.3 NS	10.2 ± 0.36 NS
GF 677	Virgin soil	1.10 ± 0.04 b	148.5 ± 5.8 b	9.5 ± 0.20 NS	1.20 ± 0.05 NS	166.4 ± 4.0 NS	9.8 ± 0.21 b
	Replant soil	0.77 ± 0.07 a	125.1 ± 4.0 a	9.9 ± 0.21 NS	1.19 ± 0.06 NS	156.6 ± 3.3 NS	9.2 ± 0.14 a
Adesoto	Virgin soil	0.77 ± 0.10 a	136.1 ± 3.8 NS	10.2 ± 0.15 NS	1.04 ± 0.04 NS	156.7 ± 3.8 NS	8.9 ± 0.29 NS
	Replant soil	1.11 ± 0.05 b	145.2 ± 6.1 NS	10.6 ± 0.20 NS	1.13 ± 0.07 NS	159.8 ± 4.1 NS	9.3 ± 0.22 NS
Julior	Virgin soil	0.50 ± 0.23 NS	145.4 ± 2.8 NS	11.0 ± 0.29 b	1.06 ± 0.06 NS	146.0 ± 2.5 NS	10.0 ± 0.21 b
	Replant soil	0.61 ± 0.13 NS	158.4 ± 5.9 NS	10.2 ± 0.25 a	1.16 ± 0.06 NS	153.5 ± 2.5 NS	9.2 ± 0.32 a
Penta	Virgin soil	0.38 ± 0.07 a	158.7 ± 4.5 NS	10.7 ± 0.29 b	1.15 ± 0.06 NS	151.5 ± 5.3 NS	9.8 ± 0.29 NS
	Replant soil	1.15 ± 0.08 b	144.9 ± 3.5 NS	9.2 ± 0.22 a	1.31 ± 0.06 NS	152.3 ± 3.3 NS	9.2 ± 0.25 NS
Tetra	Virgin soil	0.44 ± 0.08 NS	152.3 ± 4.8 NS	10.6 ± 0.33 NS	1.17 ± 0.03 a	152.2 ± 3.5 NS	10.3 ± 0.22 NS
	Replant soil	0.71 ± 0.12 NS	152.9 ± 6.4 NS	10.6 ± 0.19 NS	1.38 ± 0.04 b	149.8 ± 3.5 NS	10.2 ± 0.18 NS
MrS 2/5	Virgin soil	0.36 ± 0.07 a	144.6 ± 4.6 NS	10.6 ± 0.27 b	1.17 ± 0.05 NS	147.1 ± 3.9 NS	10.7 ± 0.30 b
	Replant soil	1.20 ± 0.06 b	152.9 ± 6.4 NS	9.1 ± 0.21 a	1.30 ± 0.05 NS	149.2 ± 3.8 NS	9.4 ± 0.20 a
Peach seedling	Virgin soil	0.70 ± 0.09 NS	150.4 ± 5.7 NS	10.7 ± 0.46 b	1.22 ± 0.06 NS	170.7 ± 6.7 NS	10.1 ± 0.24 b
	Replant soil	0.60 ± 0.09 NS	156.2 ± 4.6 NS	9.4 ± 0.19 a	1.24 ± 0.04 NS	161.4 ± 5.1 NS	8.9 ± 0.18 a

NS, non-significant; different letters denote statistically significant differences between the two soil types of a particular rootstock using one-way analysis of variance (LSD test with P-value < 0.05)

stocks significant decrease of soluble solids was noted when the trees were growing in replant soil.

Rootstock effect on fruit maturity

On the basis of fruit firmness and ground colour, the rootstocks were grouped according to their effect on fruit maturity. With the use of cluster analysis (Fig. 1A, 1B), three distinct groups of rootstocks of similar fruit maturity were formed in each soil type in 2008, while 4 groups were formed in 2009 (Fig. 1C, 1D). In 2008, Julior rootstock delayed maturity the most in virgin soil, producing the firmest fruit with intense red coloration. The second group consisted of Cadaman, GF 677 and Tetra rootstocks, where again firm fruit were typical; however, poor coloration was also noted (low a* values – more green coloration). Daza et al. (2008) found Cadaman and GF 677 rootstock to delay maturity of Japanese plums. Finally, the third group (Adesoto, Barrier 1, Monegro, MrS 2/5, Penta and peach seedling rootstock) progressed fruit ripening according to fruit firmness (soft fruit) and ground colour (red coloration). Reighard et al. (2008) also found Adesoto and MrS 2/5 to mature earliest. In replant soil Monegro rootstock delayed fruit ripening the most. The second group (Adesoto, Penta, Tetra and Julior rootstock) progressed fruit maturation compared to Monegro. The ripest 'Redhaven' peaches were harvested from Barrier 1, Cadaman, GF 677, peach seedling and MrS 2/5 rootstock in replant soil. This is in contradiction with Remorini et al. (2008) who reported Barrier 1 to delay maturity.

In 2009 fruit from Julior rootstock grafted trees stood out for their high fruit firmness and high a* values when growing in virgin soil. GF 677 caused delayed maturity (high fruit firmness and low a* values). The third group consists of Cadaman, Penta and peach seedling rootstocks, which served to advance maturation. The last group of rootstocks (Barrier 1, Monegro, Adesoto, MrS 2/5, and Tetra) produced the ripest fruit. In replant soil fruit collected from Julior and Cadaman was firmest and well coloured. GF 677 rootstock delayed maturation but also caused poorer coloration of the fruit. Penta and Tetra produced soft fruit with good red coloration in replant soil and were ranked in the third group. The last group that significantly advanced ripeness in replant soil consisted of Barrier 1, Monegro, Adesoto, MrS 2/5 and peach seedling. According to our results, rootstock selection and performance play an important role in fruit maturity, one that was in generally consistent over the two seasons.

Rootstock and soil type affecting the chemical characteristics of 'Redhaven'

Sucrose is the most abundant sugar in peach fruit, representing from 69 to 77 % in 2008 and from 78 to 87 % of total sugars in 2009. Glucose and fructose each represented from 9 to 17 % in 2008 and from 5 to 11 % of total sugars in 2009. Sorbitol was present in the lowest quanti-

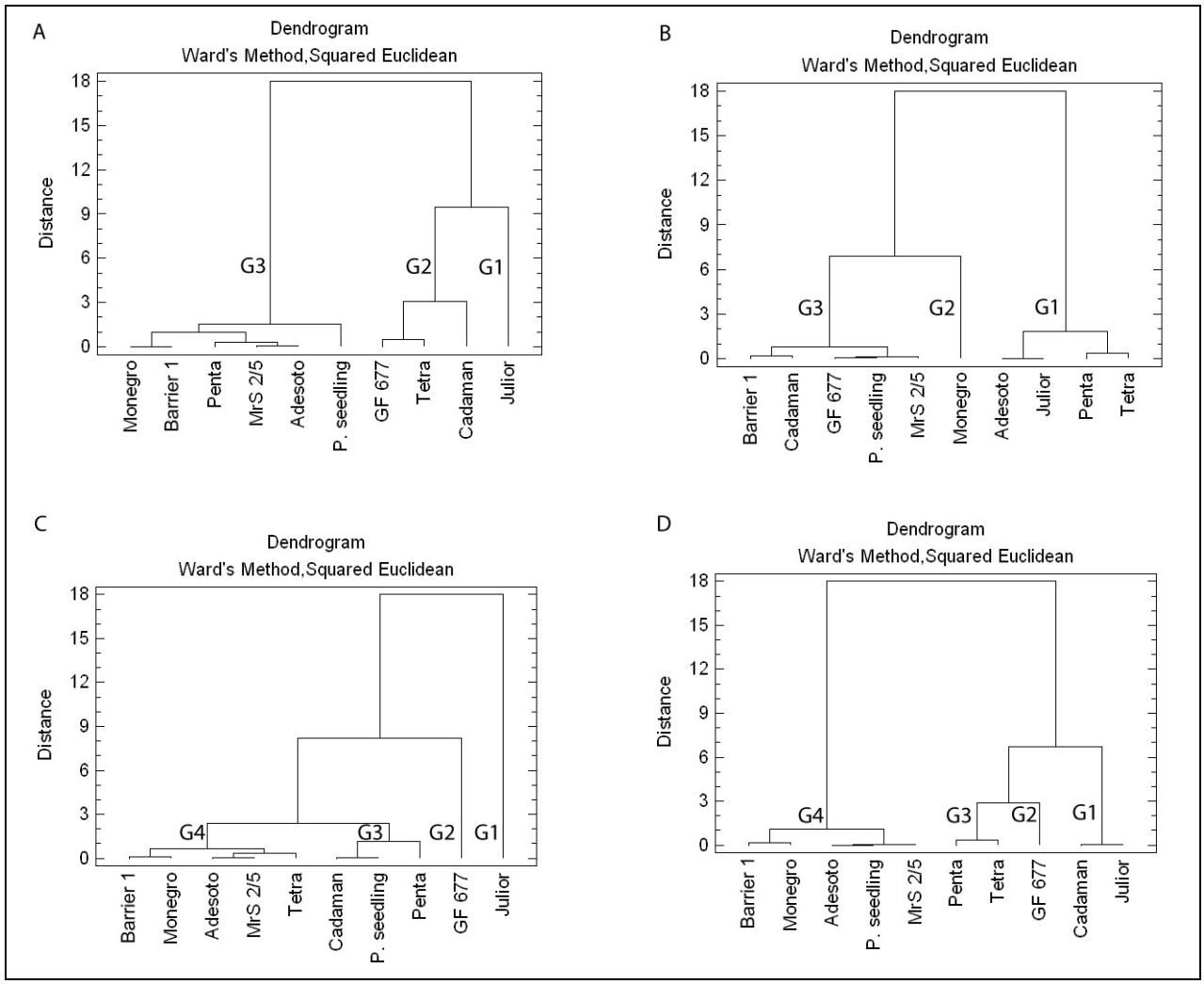


Fig. 1. Dendrograms of ten peach rootstocks in virgin (A) and replant soil (B) in 2008 and in virgin (C) and replant soil (D) in 2009 using the ward method based on the square Euclidean distance from fruit firmness and ground colour. G 1 to G 4 represents different groups of fruit maturity.

ties, representing from 0.5 to 2.5 % in 2008 and from 2 to 4 % of total sugars in 2009. Similar results were previously reported by Génard and Souty (1996) and Colaric et al. (2005). Significant effect of the rootstocks (statistics not shown) and of the soil type (Fig. 2A) on total sugars was noted in both seasons. In 2008, significantly higher contents of total sugars were measured in fruit from most trees growing in virgin soil. In fruit harvested from peach seedling trees statistically similar contents of total sugars were measured in both soil types. In 2009, fruit from several rootstocks (Cadaman, GF677, Adesoto, Penta and Tetra) contained similar total sugars levels in both soil types (Fig. 2B). In fruit from all other rootstocks, significant decrease of total sugars levels was noted when growing in replant soil.

Malic acid was present at highest percent among organic acids, representing from 60 to 84 % in 2008 and from 69 to 85 % in 2009 of total organic acids. Citric acid was the second most abundant organic acid in peach, representing from 15 to 38 % in 2008 and from 16 to 32 % in 2009 of total organic acids. These levels are in accordance with those reported by Colaric et al. (2005). Similar proportions of major organic acids were determined for both seasons despite lower levels in 2009. Two minor organic acids (shikimic and fumaric acid), were also identified and quantified, which represented less than 1 % of total organic acids combined.

In 2008, fruit from several rootstocks (Barrier 1, GF 677, Penta, Tetra, MrS 2/5 and peach seedling) contained similar levels of total organic acids in both soil types (Fig. 3A). In fruit harvested from Cadaman, Monegro and Julior rootstocks significant decrease in total organic acids was noted in replant soil compared to virgin soil. Only in fruit from Adesoto rootstock significantly higher levels of total organic acids were measured in replant soil. In 2009, fruit from most rootstocks (Monegro, GF 677, Adesoto, Penta and MrS 2/5) was unaffected by the soil type in terms of total organic acids content (Fig. 3B). In fruit from several rootstocks (Barrier, Cadaman, Julior and peach seedlong) higher content levels of organic acids were measured when growing in replant soil. Only in fruit from Tetra grafted trees growing in virgin soil higher levels of organic acids were measured compared to replant soil.

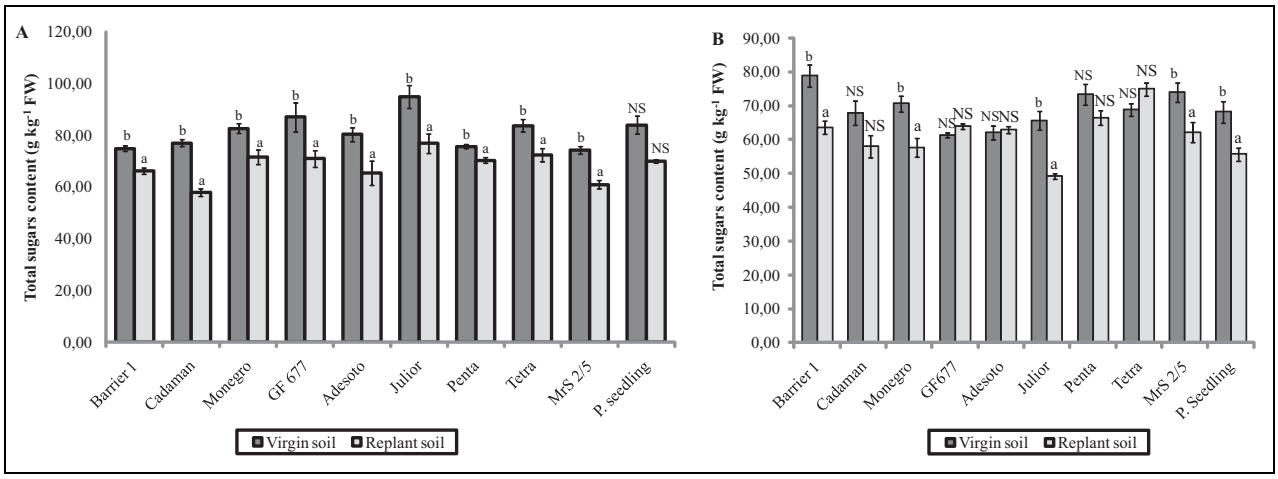


Fig. 2. Total sugar content in 2008 (A) and 2009 (B) and in 'Redhaven' peach fruit grafted on ten rootstocks. Different letters denote statistically significant differences between the two soil types for individual rootstocks using one-way analysis of variance (LSD test with P-value < 0.05)

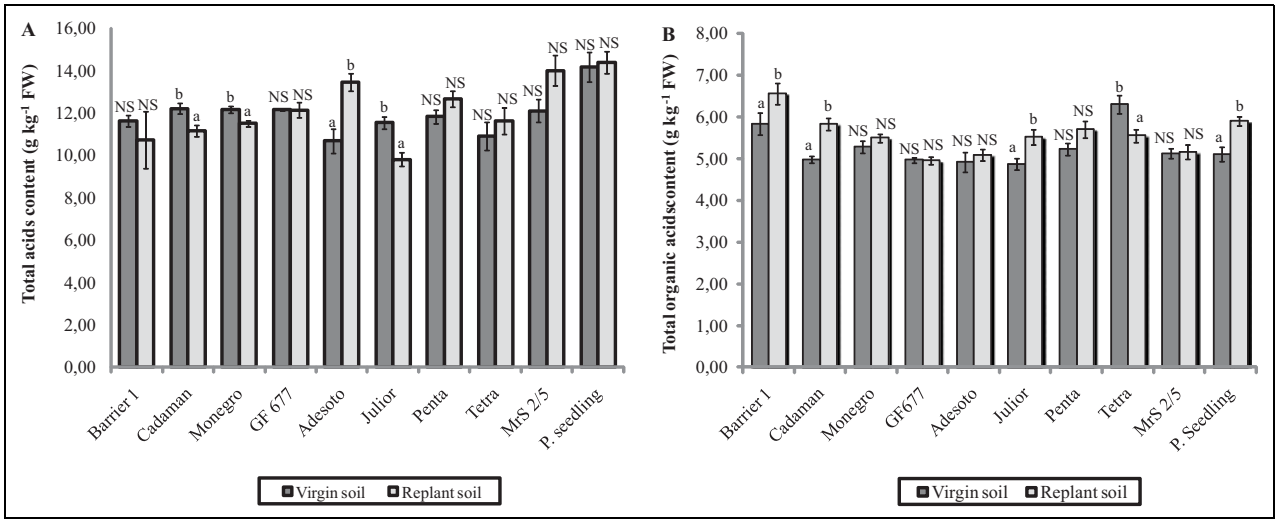


Fig. 3. Total organic acids content in 2008 (A) and 2009 (B) and in 'Redhaven' peach fruit grafted on ten rootstocks. Different letters denote statistically significant differences between the two soil types for individual rootstocks using one-way analysis of variance (LSD test with P-value < 0.05)

The sugars/organic acids ratio varied greatly and was strongly rootstock dependant (Fig. 4). According to COLARIC et al. (2005) the sugars/organic acids ratio correlates positively with the perception of sweetness in peach fruit. All rootstocks produced sweeter fruit in virgin soil; nevertheless, statistically Barrier 1, Monegro and Julior rootstocks produced similarly sweet fruit in both soil types in 2008. In 2009, for the majority of rootstocks virgin soil again yielded sweeter fruit. A similar sugars/organic acids ratio in both soil types was found in fruit harvested from GF 677, Adesoto and MrS 2/5 rootstocks grafted trees. Only Tetra rootstock caused a higher ratio of sugars/organic acids when planted in replant soil.

Conclusion

The study provides general information about the quality of 'Redhaven' peach in our growing conditions and the contributing extent of rootstock effect. New rootstocks of different vigour were highlighted for use in new orchards as a substitute for the peach seedlings and GF 677 presently in use. Our results also provide valid recommendations as to which rootstocks to use in numerous orchards in the Mediterranean region that need to be renewed.

The effect of ten rootstocks on vegetative growth was evaluated. Soil type affected vegetative growth, since different ranking according to vigour was established when comparing soil types. The following ranking of tree vigour was established in 2009 in virgin soil: GF 677 > Barrier 1 > Monegro > Julior > Cadaman = Adesoto > peach seedling = Tetra > MrS 2/5 > Penta while in the same season in replant soil was as follows: Monegro > Barrier 1 = Cadaman > GF 677 > Adesoto > MrS 2/5 > Julior > Tetra > Penta > peach seedling.

We found that rootstock influences the duration of fruit development. Two-year results indicate that Cadaman,

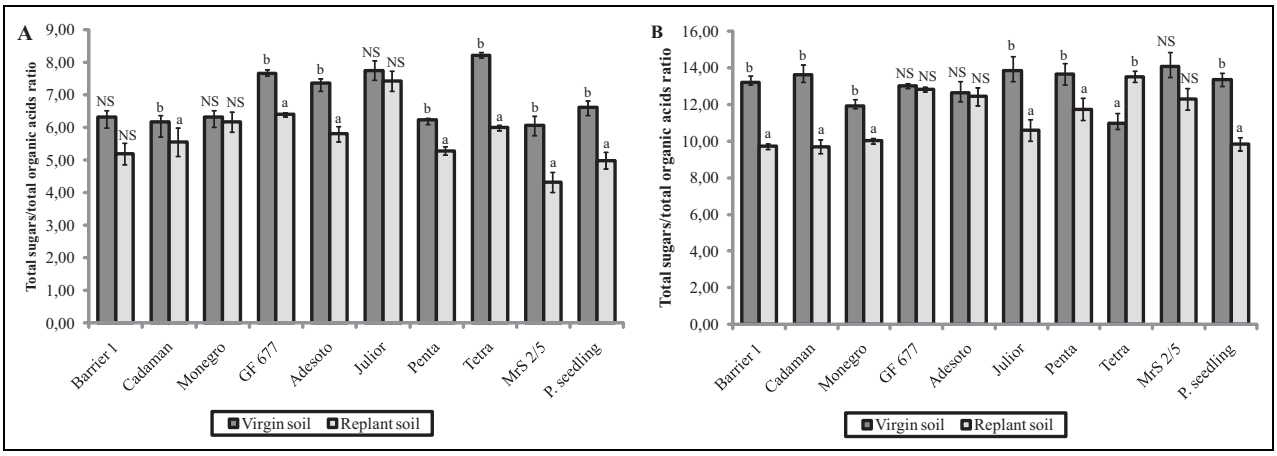


Fig. 4. Sugars/organic acids ratio in 2008 (A), sugars/organic acids ratio in 2009 (B) and in 'Redhaven' peach fruit grafted on ten rootstocks. Different letters denote statistically significant differences between the two soil types for individual rootstocks using one-way analysis of variance (LSD test with P-value < 0.05)

GF 677 and Julior rootstocks delay maturity. On the other hand Adesoto, Barrier 1, Monegro, MrS 2/5, Penta and peach seedling induced early maturity. GF 677 and Barrier 1 produced poor quality fruits in 2008; however they improved their performance in 2009 regarding fruit weight as well as most of the chemical parameters. Among the rootstocks tested in virgin soil Julior, Penta, Monegro, MrS 2/5 and peach seedling performed best in terms of 'Redhaven' quality. High values of soluble solids content, total sugars and organic acids were characteristic of these rootstocks and should be promoted for planting new orchards. In replant soil, Adesoto, Penta and Tetra rootstock produced the highest quality fruit. Several fruit quality parameters showed no significant differences between the two soil types for these rootstocks; therefore, these rootstocks would be the best recommendation for replantation of peach orchards in the Mediterranean region. According to our results, 'Redhaven' peach fruit on rootstocks planted in replant soil had lower content levels of total sugars and higher levels of total organic acids. Consequently, lower general fruit quality at the same ripeness was detected compared to virgin soil, a finding that is also consistent through years. These facts imply that rootstock and soil type both greatly affect the taste of the 'Redhaven' peach cultivar and that there are some rootstocks, which are better suited for each of the soil conditions.

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