UNIVERZA V LJUBLJANI
BIOTEHNIŠKA FAKULTETA

Primož ORAŽEM

VPLIV RAZLIČNIH PODLAG NA KAKOVOST PLODOV BRESKVE SORT 'ROYAL GLORY' IN 'REDHAVEN' NA DEVIŠKIH IN UTRUJENIH TLEH

DOKTORSKA DISERTACIJA

Ljubljana, 2013

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INFLUENCE OF DIFFERENT ROOTSTOCKS ON FRUIT QUALITY OF 'ROYAL GLORY' AND 'REDHAVEN' CULTIVAR ON VIRGIN AND REPLANT SOIL

DOCTORAL DISERTATION

Ljubljana, 2013

Doktorska disertacija je zaključek Podiplomskega študija bioloških in biotehniških znanosti ter se nanaša na znanstveno področje agronomije. Poskus je bil zastavljen v Sadjarskem centru Bilje pri Novi Gorici. Nadaljnje raziskave in analize so bile opravljene na Katedri za sadjarstvo, vinogradništvo in vrtnarstvo Oddelka za agronomijo Biotehniške fakultete Univerze v Ljubljani.

Na podlagi Statuta Univerze v Ljubljani ter po sklepu Senata Biotehniške fakultete in sklepa Senata Univerze z dne 6. julija 2011 je bilo potrjeno, da kandidat izpolnjuje pogoje za neposreden prehod na doktorski Podiplomski študij bioloških in biotehniških znanosti ter opravljanje doktorata znanosti s področja agronomije.

Tema in naslov doktorske disertacije sta bila sprejeta na podlagi Statuta Univerze v Ljubljani ter po sklepu Senata Biotehniške fakultete in sklepa 19. seje Komisije za doktorski študij Univerze v Ljubljani (po pooblastilu 30. seje Senata Univerze v Ljubljani z dne 20. januarja 2009) z dne 6. julija 2011. Za mentorico je bila imenovana prof. dr. Metka HUDINA.

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Delo je rezultat lastnega raziskovalnega dela. Izjavljam, da so vsa vključena znanstvena dela identična objavljeni različici.

Primož ORAŽEM

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IN VPLIV RAZLIČNIH PODLAG NA KAKOVOST PLODOV BRESKVE SORT ‘ROYAL GLORY’ IN ‘REDHAVEN’ NA DEVIŠKIH IN UTRUJENIH TLEH

TD Doktorska disertacija

OP VI, 53, [2] str., 1 pregl., 1 pril., 69 vir.

IJ sl

JI sl/en

AI V raziskavi smo leta 2008 in 2009 spremljali pridelek, bujnost in nekatere parametre kakovosti plodov breskve pri sortah ‘Redhaven’ in ‘Royal Glory, posajenih na deviška in utrujena tla ter cepljenih na enajst različnih podlag (‘Adesoto’, ‘Barrier 1’, ‘Cadaman’, ‘GF 677’, ‘Julior’, ‘Ishtara’, ‘MrS 2/5’, ‘Monegro’, ‘Penta’, sejanec in ‘Tetra’). Leta 2008 so imele podlage pri sorti ‘Redhaven’ značilen vpliv na maso in zorenje plodov. Podlaga ‘Julior’ je na deviških tleh vplivala na poznejše dozorevanje plodov v obeh letih, na utrujenih pa le leta 2009. Na deviških tleh so bili plodovi ne glede na podlago boljše notranje kakovosti (večja vsebnost skupnih sladkorjev) kot na utrujenih tleh. Za najboljše podlage na deviških tleh so se izkazale ‘Barrier 1’, ‘GF 677’ in sejanec, medtem ko smo na utrujenih tleh najboljše rezultate zabeležili pri podlagah ‘Adesoto’, ‘Tetra’ in ‘Penta’, kjer so plodovi imeli večje vsebnosti suhe snovi, skupnih sladkorjev in organskih kislin. Ugotovili smo, da so imele podlage podoben vpliv na bujnost rasti dreves obeh sort, sorta ‘Royal Glory’ pa je rasla bujnejše od sorte ‘Redhaven’. Podlaga ‘Ishtara’ je vplivala na šibko rast dreves, podlage ‘Adesoto’, ‘Penta’ in sejanec na srednje bujno ter podlage ‘Barrier 1’, ‘GF 677’ in ‘Monegro’ na bujno rast dreves. Sorta ‘Redhaven’ je na vseh podlagah imela značilno večji pridelek v primerjavi s sorto ‘Royal Glory’, medtem ko znotraj posamezne sorte vpliva podlag na pridelek nismo zabeležili. Pri sorti ‘Redhaven’ podlage niso vplivale na vsebnost suhe snovi, medtem ko smo pri sorti ‘Royal Glory’ ugotovili značilen vpliv na ta parameter. V plodovih obeh sort smo ugotovili razlike v vsebnosti posameznih sladkorjev, organskih kislin ter sekundarnih metabolitov, značilen pa je bil tudi vpliv podlag na notranjo kakovost posamezne sorte. Ugotovili smo tudi, da so se fenolne kisline v mesu in kožici pri obeh sortah spreminjale bolj, kot so se spreminjali ostali sekundarni metaboliti.

KEY WORD DOCUMENTATION

ŠD	Dd
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KG	peach/rootstock/fruits/carbohydrates/organic acids/phenolics
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IJ	sl
JI	sl/en

AI Experiment was conducted in 2008 and 2009 on cv. 'Redhaven' and only in 2009 on cv. 'Royal Glory' grafted on eleven different rootstocks ('Adesoto', 'Barrier 1', 'Cadaman', 'GF 677', 'Julior', 'Ishtara', 'MrS 2/5', 'Monegro', 'Penta', peach seedling and 'Tetra'). Yield, vigor and several quality parameters were monitored. Rootstocks at cv. 'Redhaven' influenced differences in fruit weight in 2008. Rootstocks also influenced harvest maturity. 'Julior' rootstock influenced late ripening of cv. 'Redhaven' in replant soil in 2009 and in virgin soils in both years. 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 seedling rootstocks adapted best to virgin soil conditions, while in replant soil, 'Adesoto', 'Tetra' and 'Penta' showed greatest potential since in fruit from these rootstocks higher soluble solids contents, total sugars and organic acids were found. A uniform effect of rootstock on tree size was evident in the cases of both cultivars, while cv. 'Royal Glory' was more vigorous compared to cv. 'Redhaven'. The 'Ishtara' rootstock induced weak tree growth; 'Adesoto', 'Penta' and peach seedling semi vigorous growth; and 'Barrier 1', 'GF 677', and 'Monegro' vigorous tree growth. Higher yield was recorded at cv. 'Redhaven' compared to cv. 'Royal Glory', while no significant differences in yield were found among the rootstocks for both cultivars. Rootstocks had no effect on soluble solids content at cv. 'Redhaven', while at cv. 'Royal Glory' they did. In the fruit from both cultivars, the rootstock had a significant influence on individual sugars, organic acids, and phenolic acids in the pulp. We also found that phenolic acids in the pulp and skin were more affected by the rootstock than other secondary metabolites analyzed, regardless of the cultivar.

KAZALO VSEBINE

KAZALO PREGLEDNIC

Str.

1 PREDSTAVITEV PROBLEMATIKE IN HIPOTEZE

Breskev (*Prunus persica* Batch. L.) je gledano z vidika pridelave zanimiva predvsem zaradi razmeroma zgodnega začetka zorenja v primerjavi z drugimi sadnimi vrstami. Zgodnje sorte breskev, ki se praviloma slabo ločijo od koščice, začnejo zoreti že konec junija oziroma na začetku julija. V tem obdobju med sadnimi vrstami poleg češnje zori le še marelica, zato je breskev kot sezonsko sadje tržno zelo zanimiva. Čas zorenja breskve določamo glede na zorenje sorte 'Redhaven', ki jo zato označujemo kot standardno sorto. Zorenje poznih sort breskev pa se, predvsem v hladnejših predelih, lahko zavleče tudi v september.

Po dosegljivih statističnih podatkih je bilo v svetovnem merilu leta 2010 pridelovanje breskev in nektarin ocenjeno na 1.538.682 ha zemljišč. Skupni svetovni pridelek leta 2010 je bil ocenjen na 20.528.283 t. Pri obeh podatkih je viden trend povečevanja pridelave (FAOSTAT, 2012).

V Sloveniji breskve tradicionalno pridelujemo v Vipavski dolini, Goriških brdih in delih slovenske Istre ter tudi nekaterih, predvsem nižjih legah Štajerske in Dolenjske. Statistični podatki za Slovenijo kažejo, da breskve pridelujemo na okrog 510 ha (SURS, 2009), kar to sadno vrsto uvršča na tretje mesto za jablano in oljko. Po količini pridelave se z letnim pridelkom okrog 5700 t (SURS, 2009) uvršča na drugo mesto, takoj za jablano. V zadnjih letih opažamo trend opuščanja pridelave breskev, ki je razviden tako iz zmanjšanja obsega zasajenih zemljišč, kakor tudi zmanjšane skupne količine letnega pridelka. Zmanjšanje lahko pripišemo nizkim odkupnim cenam v zadnjih letih in posledično manjši tržni zanimivosti te sadne vrste.

Sorta 'Redhaven' izvira iz ZDA, kjer je nastala s križanjem sort 'Halehaven' × 'Kalhaven'. Zanjo je značilna srednje bujna rast, dobra in redna rodnost ter srednje pozno cvetenje. Njena osnovna barva je zlato rumena, ki jo na 80 % plodu prekriva živahno rdeča prižasta krovna barva. Meso je rumeno oranžno, pri koščici lahko nekoliko rdečkasto, topno, odličnega okusa in se dobro loči od koščice. Zori v zadnji dekadi julija (povprečni čas zorenja na Primorskem je med 22. in 25. julijem) (Godec in sod., 2011). Sorta 'Royal Glory' je prav tako ameriškega porekla in je nastala s prosto oprašitvijo sorte 'May Grand'. Osnovna barva kožice je rumena, vendar je praviloma skoraj v celoti prekrita s temno rdečo krovno barvo. Prav tako gre za rumeno mesnato sorto, ki se lepo loči od koščice, je sočna, sladko kislega in aromatičnega okusa. Zori pet dni pred sorto 'Redhaven' (Godec in sod., 2011).

Podlaga je eden od najpomembnejših dejavnikov, ki vplivajo na donosnost pridelave v sadjarstvu. Omogoča nam razmeroma prožen in najcenejši način nadzora bujnosti dreves (Webster, 1993). Podlage vplivajo na rast in razvoj sadik in pogojujejo vzdrževanje sadovnjaka (Layne, 1994). Rod *Prunus* je z vidika skladnosti dobro prilagodljiv. Breskve uspešno cepimo na podlage različnega genetskega izvora (Hudina in sod., 2006), zato je, podobno kot pri drugih sadnih vrstah, tudi pridelovalcem breskev na voljo več podlag.

Slovenski sadjarji so pri zasaditvi prve generacije breskovega sadovnjaka uporabili sejanec breskve in za njim podlago 'GF 677', ki je križanec breskve in mandlja.

1.1 VPLIV PODLAG NA VEGETATIVNE LASTNOSTI DREVESA

Eden najočitnejših vplivov podlage se pri drevesu odrazi v njegovi bujnosti rasti. O razlikah v bujnosti dreves, cepljenih na različne podlage, poročajo Mullins in Straw (1990) ter Elfying in Schechter (1993) pri jablani, Rivalta in sod. (1989) ter Jacob (2000) pri hruški, Kosina (2011) ter Hrotkó in sod. (2002) pri slivi, Usenik in sod. (2006, 2010b) pri češnji, ter Hudina in sod. (2006), Chanana in sod. (2009) in Layne (1994) pri breskvi.

Hudina in sod. (2009) so pri sorti 'Redhaven' raziskovali vpliv enajstih različnih podlag breskev na obseg debla posameznih dreves. Kasneje so na podlagi razlik v obsegih debla dreves, podlage breskev razvrstili v tri skupine, in sicer:

- šibke podlage: 'Tetra' in 'Ishtara';
- srednje bujne podlage: 'GF 677', sejanec breskve, 'Penta', 'Julior', 'Adesoto' in 'MrS 2/5';
- bujne podlage: 'Monegro', 'Barrier 1' in 'Cadaman'.

Do podobnih rezultatov in razvrstitve podlag so prišli tudi Reighard in sod. (2008). Podlaga 'Cadaman' se je v njihovi študiji izkazala za najbujnejšo, medtem ko so bile podlage 'Julior', 'Adesoto' in 'MrS 2/5' najšibkejše med proučevanimi podlagami, med njimi pa ni bilo statistično značilnih razlik.

Vrsta podlage pa vpliva tudi na rodnost dreves. Po poročanju avtorjev Mullins in Straw (1990) podlage vplivajo na količino pridelka pri jablani. Usenik in sod. (2010a) so v svoji raziskavi ugotovili, da nekatere šibke podlage lahko vplivajo na preveliko rodnost somooplodnih sort češenj, kar se ob odsotnosti redčenja lahko kaže v slabi kakovosti plodov. Prav tako Hudina in sod. (2006) poročajo o značilnem vplivu podlag na pridelek breskve. Seveda je potrebno poudariti, da šibkejše podlage omogočajo manjšo velikost dreves in s tem večjo gostoto sajenja ter posledično večje hektarske pridelke sadovnjakov.

1.2 VPLIV PODLAG NA FENOLOŠKE FAZE

Nekatere raziskave (Lichev in Papachatzis, 2006; Karlidag in Ercisli, 2010) so pokazale, da podlaga vpliva tudi na občutljivost dreves na pozebo. V prvi raziskavi (Lichev in Papachatzis, 2006), kjer so obravnavali deset češnjevih podlag, cepljenih s sorto 'Bigarreau burlat', so avtorji ugotovili, da drevesa, cepljena na šibke podlage ('Gisela 5'), slabo prenašajo pozebo, medtem ko drevesa, cepljena na sejanec, ob nizkih temperaturah niso utrpela večje škode. Do podobnih zaključkov sta pri drevesih marelice prišla tudi avtorja Karlidag in Ercisli (2010), ki poročata, da so bila drevesa, cepljena na sejanec, med cvetenjem marelic bolj odporna na nizke temperature kot drevesa, ki so bila cepljena na šibkejše podlage. O podobnih pozitivnih učinkih bujnejših podlag pri pozebi piše tudi Durner (1990).

Poznan je tudi vpliv podlag na fenološke faze drevesa. Anderson in sod. (1996) so pri višnji sorte 'Montmorency', cepljeni na različne podlage, ugotovili do pet-dnevne razlike v času njenega cvetenja. Blažková in sod. (2010) navajajo minimalen vpliv štirih šibkih podlag na čas cvetenja češnje. V podobni raziskavi se je pri breskvi sorte 'Redhaven' čas cvetenja v posameznem letu razlikoval do devet dni (Beckman in sod., 1992). Do podobnih ugotovitev so prišli tudi Kubota in sod. (2001). Beckman in sod. (1992) še navajajo, da je vstop drevesa v fenofazo cvetenja odvisen od efektivnih temperatur. V svoji razpravi ugotavljajo, da na legah severnih zemljepisnih širin redko pride do občutnih razlik v času cvetenja, medtem ko so na južnih zemljepisnih širinah te razlike bolj očitne. Iglesias in sod. (2004) pa niso ugotovili značilnih razlik v času cvetenja pri breskvi sorte 'Elegant Lady', cepljeni na šest različnih podlag.

Druga fenološka faza, na katero vplivajo podlage, je čas obiranja oziroma trajanje dozorevanja plodov. V raziskavi na šibkih podlagah jablane so ugotovili, da posamezne podlage vplivajo na poznejše dozorevanje plodov (Autio, 1991). Prav tako Beckman in sod. (1992) pri breskvi poročajo, da so posamezne podlage vplivale na hitrejše zorenje sorte 'Redhaven'. Kljub istočasnemu cvetenju sorte 'Redhaven' na različnih podlagah tudi Iglesias in sod. (2004) navajajo značilne razlike v dozorevanju plodov.

1.3 ZRELOST IN KAKOVOST PLODOV BRESKVE

Breskev spada v skupino klimakteričnih plodov, kar pomeni, da je zorenje odvisno od sinteze etilena, ki povzroči spremembe fizikalnih in kemičnih lastnosti (Grierson, 1987). Te spremembe vplivajo na senzorične lastnosti plodov, kot so na primer barva plodov, vonj, okus in tekstura, vse našteto pa pomembno vpliva tudi na všečnost pri kupcih (Leshem in sod., 1986). Žal se pogosto dogaja, da breskev na prodajnih policah ne dosega okusa, ki ga kupci zahtevajo. Razlog je v tem, da se stopnja zrelosti, ki jo želi kupec, razlikuje od stopnje zrelosti, ki jo zahteva in kasneje ponuja prodajalec.

Za ugotavljanje zrelosti plodov je na razpolago veliko metod, ki jih lahko razdelimo na destruktivne in nedestruktivne. Prva skupina določa večinoma pomološke, druga pa predvsem biokemične lastnosti plodov. Nekatere nedestruktivne metode lahko uporabimo kot kazalnike zrelosti, in sicer so med njimi najbolj proučevane meritve barve plodov (Delwiche in Baumgardner, 1985). Slednja poročata, da so posamezni parametri koloroimetričnih meritev (CIELAB) osnovne barve breskve v tesni povezavi s stopnjo zrelosti plodov. Crisosto (1994) se v svojem preglednem članku strinja, da so meritve osnovne barve najbolj praktičen in najpogosteje uporabljen kazalnik minimalne zrelosti, a hkrati opozarja, da ima ta metoda tudi svoje pomanjkljivosti. Pri nekaterih sortah breskve se je namreč izkazalo, da krovna barva prekriva celotno kožico in so zato pri takih sortah meritve osnovne barve nemogoče. Kot drugi pomemben kazalnik polne zrelosti plodov breskve navaja trdoto plodov in dodaja, da kombinacija obeh omenjenih kazalnikov bolje opiše zrelost plodov kot pa posamičen kazalnik sam. Vsebnost suhe snovi ni zanesljiva metoda določanja zrelosti, saj so med lokacijami in celo med drevesi ugotovili veliko variabilnost. Nekatere novejše metode (meritve bližnjega infrardečega valovanja, meritve magnetne resonance in transmisija svetlobe) pa bi lahko pripeljale do zanesljivejših nedestruktivnih kazalnikov zrelosti (Crisosto, 1994).

Zunanja kakovost plodov je pojem, ki zajema številne lastnosti plodov. Te so v prvi vrsti odvisne od izbire sorte in podlage (Esti in sod., 1997; Hudina in Štampar, 2000a), pomembno pa nanje vplivajo tudi ostali okoljski dejavniki (nadmorska višina sadovnjaka, letne temperature, količina padavin, osvetljenost, lastnosti tal) ter tehnološki ukrepi (gojitvena oblika, rez, toletni in lanskoletni pridelek, redčenje, prehranjenost dreves, način namakanja, ukrepi varstva rastlin, itd.). Vsi ti dejavniki vplivajo na velikost, maso in izgled plodov.

Notranjo kakovost zdravih plodov prav tako določata sorta (Esti in sod., 1997; Hudina in Štampar, 2000b) ter zrelost plodov (Wang in sod., 1993; Hudina in Štampar, 2000a; Wu in sod., 2005). Najosnovnejša kazalnika notranje kakovosti plodov sta vsebnost suhe snovi in titracijskih kislin. Z natančnejšimi metodami lahko določimo in ovrednotimo tako primarne kot sekundarne metabolite. Vsebnosti in razmerja med primarnimi metaboliti (sladkorji in organskimi kislinami) močno vplivajo na senzorične lastnosti plodov (Colaric in sod., 2005). Med sladkorji v breskvi prevladuje saharoza, ki po navedbah avtorjev Byrne in sod. (1991) ter Colaric in sod. (2005) predstavlja do 60 % vseh sladkorjev. Sledita ji glukoza in fruktoza, ki sta prisotni v podobnih količinah. Med organskimi kislinami prevladuje jabolčna kislina, ki v plodovih breskve predstavlja okrog 60 % skupnih organskih kislin. Vsebnosti citronske in kininske kisline sta zelo podobni, skupaj pa predstavljata 40 % delež skupnih organskih kislin (Byrne in sod., 1991; Colaric in sod., 2005). Druge organske kisline (šikimska kislina) so prisotne v mnogo manjših količinah (Wu in sod., 2005).

Lesnate rastline iz ogljikovih hidratov, organskih kislin, aminokislin in maščob proizvajajo različne sekundarne metabolite, med katerimi fenolne snovi veljajo za ene najpomembnejših. Na ravni rastline so številne raziskave pokazale, da fenolne spojine delujejo tako, da inducirajo ali zavirajo sintezo rastlinskih hormonov (Kozlowski in Pallardy, 1996). Poleg tega je dobro znana tudi vloga sekundarnih metabolitov pri zaščiti rastlin pred napadi herbivorov in mikrobov, služijo pa tudi kot atraktanti za opraševalce (Taiz in Zeiger, 2006). MacHeix in sod. (1990) poročajo, da fenolne snovi v plodovih vplivajo na senzorične lastnosti plodov kot so: aroma, trpkost, grenkost in obarvanost.

Na plodovih breskve so že opravili številne kemične analize ter z metodami visokoločljivostne tekočinske kromatografije (HPLC) določili številne fenolne snovi. Podobno kot pri drugih sadnih vrstah je večina fenolnih snovi prisotna v kožici plodov. Tomás-Barberán in sod. (2001) ter Andreotti in sod. (2008) v plodovih breskve od hidroksicimetnih kislin navajajo klorogensko in neoklorogensko kislino, od flavan 3-olov katehin, epikatehin in polimere procianidinov, od flavonolov pa kvercetin 3-O-galaktozid, kvercetin 3-O-glukozid, kvercetin 3-O-rutinozid. Predvsem v kožici plodov pa so v relativno visokih vsebnostih našli tudi antociana cianidin 3-O-glukozid ter cianidin 3-O-rutinozid.

1.4 BRESKEV IN PROBLEM UTRUJENIH TAL

Zmožnost prilagoditve podlag na različne pedolkimatske razmere postaja vedno pomembnejše merilo pri izbiri podlage. Prilagoditev je v veliki meri odvisna od genetskega izvora podlage (Layne, 1994; Layne in Jui, 1994; Iglesias in sod., 2004). Eden od problemov, ki se pri breskvi pojavlja v različnih pedoklimatskih razmerah je ta, da sadika te sadne vrste ne prenese ponovnega sajenja na isto mesto. Tla, kjer so predhodno že rasle breskve, imenujemo utrujena tla. V agronomiji ta izraz opisuje negostoljubnost tal za ponovno sajenje enake kulture in se odrazi v njenem slabšem uspevanju (Zucconi, 1993). Savory (1969) in Zucconi (1993) sta probleme utrujenih tal razdelila na specifične in nespecifične probleme obnove. Med nespecifične probleme spadajo toksični rastlinski produkti (Zucconi, 1993; Giorgi in sod., 2005; Neri in sod., 2006), ogorčice, neenakomerna založenost tal s hranili, slaba struktura tal, zastajanje vode ter velika ali majhna pH-vrednost tal (Mai in Abawi, 1978). V tleh, kjer je predhodno že rasla rastlina iste vrste ali istega rodu, se specifični problemi obnove kažejo v slabi rasti na novo posajene rastline (Savory, 1969). Kopičenje ostankov posamezne vrste, ki se pojavi zaradi neuspešne humifikacije in izostanka stabilizacije teh ostankov, lahko privede do sproščanja toksičnih metabolitov ter pojavljanja alelopatskih simptomov (Patrick in sod., 1964; Elliott in Papendick, 1986; Zucconi, 1993).

Gur in Cohen (1989) navajata, da breskove korenine izločajo prunazin, ki se ob hidrolizi pretvori v toksično cianovodikovo kislino (HCN) in benzaldehid. Ta po avtorjevih navedbah zavira rast breskovih dreves ob ponovnem sajenju. Predvsem mlada breskova drevesa okrog koreninskega sistema ustvarijo mikrofloro, ki aktivneje hidrolizira prunazin. Posledica je slabša rast breskve ob ponovnem sajenju. Utkhede in Thomas (1988) poročata, da sliva normalno uspeva za vsemi sadnimi vrstami, razen za breskvo. Poročata tudi, da lahko breskev sadimo za vsako sadno vrsto ali trto.

Iz navedenih raziskav lahko povzamemo, da podlage na drevo vplivajo na različne načine, a mehanizmi vplivov še niso dobro raziskani. Celostno spremljanje vplivov ter identifikacija prednosti in slabosti posameznih podlag v specifičnih rastnih razmerah tako ostaja ključnega pomena za verodostojno svetovanje glede izbire podlag ob napravi novih nasadov breskev oziroma njihovi obnovi.

1.5 ZASNOVA POSKUSA IN DELOVNE HIPOTEZE

Naša raziskava je bila zasnovana v Sadjarskem centru Bilje pri Novi Gorici. Poskus je potekal na dveh poljinah. Prvo poljino označujemo kot deviška tla, saj je bila breskev na teh tleh zasajena prvič. Drugo poljino označujemo kot utrujena tla, saj je trenutni breskov nasad že tretji po vrsti. Vsaka poljina je bila razdeljena na dve podpoljini, kjer smo na prvo skupino podlag cepili sorto breskve ‘Royal Glory’, na drugo pa sorto breskve ‘Redhaven’. V poskus je bilo vključenih enajst različnih podlag, ki so navedene v preglednici 1. Dvanajst dreves posamezne podlage je naključno razporejenih v vrste, v skupinah po tri drevesa, na razdalji 4 × 2 m. Podlage so bile zasajene spomladi leta 2005, nanje pa smo avgusta istega leta cepili omenjeni sorti.

Pedološka analiza tal iz leta 2006 je pokazala, da je bila vsebnosti hranil in organske snovi v deviških tleh (5,7 mg/100 g tal P_2O_5, 21 mg/100 g tal K_2O; 1,8 % organske snovi in pH tal 7) manjša v primerjavi z vrednostmi zabeleženimi v utrujenih tleh (9,9 mg/100 g tal P_2O_5, 23 mg/100 g tal K_2O, 2,5 % organske snovi in pH tal 7). Rezultati pedološke analize iz leta 2008 so pokazali, da ni bilo razlik v založenosti deviških in utrujenih tal (16 mg/100 g tal P_2O_5, 33 mg/100 g tal K_2O, organska snov 3,5 % in pH tal 7). S skrbnim načrtovanjem gnojilnih odmerkov smo v deviških tleh nadoknadili pomanjkanje določenih elementov.

Vsako leto smo pri vsakem od obravnavanj beležili število propadlih dreves. Meritve, vzorčenje in analize smo pri sorti ‘Redhaven’ izvedli v leta 2008 in 2009, pri sorti ‘Royal Glory’ pa le leta 2009. Spomladi smo pri vseh drevesih izmerili obsege debla 20 cm nad cepljenim mestom. Ob obiranju smo vse plodove posameznega drevesa prešteli ter stehtali skupni pridelek. Pri prvem obiranju posamezne sorte smo od vsake kombinacije naključno izbrali petnajst plodov za meritve in laboratorijske analize. Na vsakem plodu smo opravili številne meritve pomoloških lastnosti (masa, velikost in trdota plodu, vsebnost suhe snovi, meritve osnovne in krovne barve kožice) kakor tudi kemične analize primarnih in sekundarnih metabolitov.

Preglednica 1: Proučevane podlage in njihov izvor

Table 1: The list of rootstocks and their origin

Ime podlage	**Izvor podlage**
‘Adesoto’	*Prunus insititia* L.
‘Barrier 1’	*Prunus persica* (L.) Batsch. × *Prunus davidiana* L.
‘Cadaman’	*Prunus persica* (L.) Batsch. × *Prunus davidiana* L.
‘GF 677’	*Prunus amygdalus* Batsch × *Prunus persica* (L.) Batsch
‘Ishtara’	(*Prunus cerasifera* L. × *Prunus salicina* Lindl.) × (*Prunus cerasifera* L. × *Prunus persica* (L.) Batsch.)
‘Julior’	*Prunus insititia* L. × *Prunus domestica* L.
‘Monegro’	*Prunus amygdalus* Batsch. × *Prunus persica* (L.) Batsch.
‘MrS 2/5’	*Prunus cerasifera* L.
‘Penta’	*Prunus domestica* L.
‘Tetra’	*Prunus domestica* L.
Sejanec breskve	*Prunus persica* (L.) Batsch.

Postavili smo te hipoteze:

- med proučevanima sortama breskev 'Redhaven' in 'Royal Glory' bodo značilne razlike v vsebnosti primarnih in sekundarnih metabolitov;
- podlage bodo vplivale na vsebnost primarnih in sekundarnih metabolitov pri posamezni sorti;
- tla bodo značilno vplivala na kakovost plodov ne le z vidika pomoloških lastnosti, ampak tudi z vidika vsebnosti primarnih in sekundarnih metabolitov; boljšo kakovost plodov pričakujemo na deviških tleh;
- okoljski dejavniki posameznega leta bodo vplivali na vsebnosti primarnih in sekundarnih metabolitov;
- enake podlage bodo vplivale na dobro kakovost plodov obeh proučevanih sort;
- pri isti sorti na različnih tleh bodo enake podlage vplivale na dobro kakovost;
- na deviških tleh bo propadlo manj dreves kot na utrujenih tleh.

Naši rezultati bodo prispevali koristne informacije o vplivu posameznih podlag breskev na kakovost plodov. Pričakujemo, da bomo na osnovi rezultatov lahko dali priporočilo, katere podlage breskev dobro uspevajo na posameznih tleh ter tako omogočajo pridelavo kakovostnih plodov.

2 ZNANSTVENA DELA

2.1 ANALIZA KAKOVOSTI PLODOV BRESKVE SORTE ‘REDHAVEN’, CEPLJENE NA ENAJST PODLAG RAZLIČNEGA GENETSKEGA IZVORA NA UTRUJENIH TLEH

ORAŽEM Primož, ŠTAMPAR Franci, HUDINA Metka

Quality analysis of ‘Redhaven’ peach fruit grafted on 11 rootstocks of different genetic origin in a replant soil

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V raziskavi smo spremljali kakovost plodov sorte ‘Redhaven’ cepljene na enajst različnih podlag, ki so bile zasajene na utrujenih tleh. Analizirali smo kemijsko sestavo in prehranske lastnosti plodov. Rezultati prinašajo koristne informacije o tem, v kakšni meri podlaga vpliva na kakovost plodov in hkrati izpostavljajo podlage, ki v kombinaciji s sorto ‘Redhaven’ v naših pedoklimatskih razmerah dajo plodove najboljše kakovosti. Izmerili smo pridelek po drevesu ter številne pomološke lastnosti (masa, trdota in obarvanost plodov ter vsebnost suhe snovi) ter jih nadgradili s HPLC analizami primarnih in sekundarnih metabolitov. Podlage so vplivale na maso plodov. Ugotovili smo tudi razlike v kazalnikih zrelosti plodov in na osnovi teh rezultatov ugotovili, da je podlaga ‘Monegro’ vplivala na poznejše dozorevanje plodov. Pri podlagi ‘Adesoto’ smo zabeležili velik pridelek na drevo ter najboljšo kakovost plodov. Tudi podlaga ‘Julior’ je pozitivno vplivala na kakovost plodov (velika vsebnost suhe snovi, posameznih in skupnih sladkorjev). Pri podlagah ‘Cadaman’ in sejanec smo zabeležili slabšo kakovost plodov, ki se je odrazila v majhni vsebnosti sladkorjev, organskih kislin in fenolnih snovi tako v mesu kot v kožici.

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Analytical Methods

Quality analysis of 'Redhaven' peach fruit grafted on 11 rootstocks of different genetic origin in a replant soil

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ABSTRACT

The fruit quality of 'Redhaven' peach [*Prunus persica* (L.) Basch.] grafted on 11 (Adesoto, Julior, GF 677, Monegro, Barrier 1, Cadaman, MrS 2/5, Ishtara, Penta, Tetra and peach seedling) experimental rootstocks was evaluated in 2008 under replant orchard conditions. Several quality indices [weight, flesh firmness (FF), ground colour measurements, and soluble solids content (SSC)] were measured, and HPLC analysis were performed for numerous chemical parameters (quantification of individual sugars, organic acids, phenolic compounds in skin and in pulp). Total phenolic content and antioxidant capacity in skin and in pulp were also measured. Julior had the heaviest fruit, while Barrier 1 and GF 677 produced fruit lighter in weight. Rootstocks influenced harvest maturity. Monegro produced the least ripe fruit, characterised by high FF, phenolic compounds in the skin and low SSC. Adesoto rootstock resulted in the best overall fruit quality (high values of SSC, individual and total sugar content levels, individual and total organic acids and phenolic compounds in pulp) as well as high total yield. Julior rootstock also produced good quality peach (high values of SSC, individual and total sugars). Cadaman and peach seedling rootstock produced 'Redhaven' fruit of the lowest quality, indicated by low values of sugars, organic acids, phenolic compounds in pulp and in skin.

1. Introduction

The rootstock represents an important consideration for a productive peach orchard, particularly in an orchard replanting situation (Bussi, Besset, & Girard, 2002). Apart from peach "seedlings", various species of stone fruit can be used as peach rootstocks, for example, plum and peach × almond hybrids. These are chosen to tolerate undesirable soil properties, such as alkalinity, waterlogging and drought (Hudina, Fajt, & Štampar, 2006). The appearance of phenomena related to soil sickness has been known for many years in the practice of replanting (Massai & Loreti, 2004). The influence of rootstocks of different genetic origin on the vigour, yield, (Bussi et al., 2002; Hudina et al., 2006; Hudina, Fajt, & Štampar, 2009; Iglesias, Montserrat, Carbó, Bonany, & Casals, 2004; Layne, 1994; Massai & Loreti, 2004; Wilkins et al., 2002) phenology (Beckman, Okie, & Meyers, 1992) and fruit quality (Albás, Jiménez, Aparicio, Betrán, & Moreno, 2004; Giorgi et al., 2005; Hudina et al., 2006) of peach trees has been well described in the literature.

The edible quality of peaches depends to a great extent on their sweetness, which is related to sugar composition (Génard & Souty, 1996). Colaric, Veberic, Stampar, and Hudina (2005) found that the amounts of sucrose, sorbitol and malic acid correlate positively with the taste and aroma of peach fruit. The amounts of individual sugars change during the ripening period of peach fruit (Génard & Souty, 1996), thus influencing the perceptual properties. Fruit phenolic compounds are also relevant in terms of fruit quality (Tomás-Barberán et al., 2001). The fruit has recently been accepted as a functional food, because of its low caloric content along with its high level of antioxidant compounds, such as vitamins, phenols, carotenoids, nitrogenous compounds, minerals and fibre, which play an important role in preventing oxidative stress (Tavarini, Degl'Innocenti, Remorini, Massai, & Guidi, 2008). Vitamin C and phenolic substances such as flavonoids are the most common among these molecules in fruit and vegetables. In recent years, there has been an increased interest in identifying and quantifying phenolic substances in fruit and vegetables to evaluate their potential health-promoting properties (Gil, Tomás-Barberán, Hess-Pierce, & Kader, 2002; Scalzo, Politi, Pellegrini, Mezzetti, & Battino, 2005) as well as their visual appearance (pigmentation and browning) and taste (astringency) (Tomás-Barberán et al., 2001). Peach fruit has relatively lower antioxidant capacities than some other fruit, for example, plum (Tomás-Barberán et al., 2001), orange (Szeto, Tomlinson, & Benzie, 2002), strawberry, apple (Scalzo et al., 2005; Szeto, Tomlinson, & Benzie, 2002), kiwifruit and apricot (Scalzo et al., 2005). However, the phenolic composition of fruit varies greatly among cultivars (Cevallos-Casals, Byrne, Okie, & Cisneros-Zevallos, 2006; Gil et al., 2002; Scalzo et al., 2005;

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Tomás-Barberán et al., 2001). The peel generally contains larger amounts of phenolics and anthocyanins than the flesh (Gil et al., 2002; Tomás-Barberán et al., 2001; Veberic & Stampar, 2005). Giorgi et al. (2005) found that the rootstock also affects the nutritional characteristics and antioxidant capacity (Scalzo et al., 2005) of peach fruit. Usenik and Stampar (2002) established that higher concentrations of phenolic substances below, above and at graft union are synthesised in heterospecific than in homospecific combinations of graft and rootstock of sweet cherry, and that the concentrations of phenols in the scion tissues are related to the rootstock used as well as to the tree vigour.

In this study, grafts of the 'Redhaven' cultivar on 11 rootstocks in replant soil were evaluated for the rootstock's effect on fruit quality. Chemical composition and nutritional characteristics of ripe fruit were also determined. The results will give us information on which rootstock provides the best fruit in replant soil in the Mediterranean region and enable us to assess whether rootstocks affect the chemical composition of peach fruit. To the best of our knowledge, the differences in individual phenolic composition among fruit from different rootstocks have not yet been evaluated. Our analysis will enable us to assess the extent of rootstock influence on certain chemical compounds in peach fruit.

2. Materials and methods

2.1. Plant material and experimental design

About 11 peach rootstocks: Adesoto (*Prunus insititia* L.), Julior (*P. insititia* L. × *Prunus domestica* L.), GF 677 (*Prunus persica* L. × *Prunus amygdalus* L.), Monegro (*P. persica* L. × *P. amygdalus* L.), Barrier 1 (*Prunus davidiana* L. × *P. persica* L.), Cadaman (*P. persica* L. × *P. davidiana* L.), MrS 2/5 (*Prunus cerasifera* Ehr.), Ishtara (*P. cerasifera* Ehr. × *Prunus salicina* Lindley.) × (*P. cerasifera* Ehr. × *P. persica* L.), Penta (*P. domestica* L.), Tetra (*P. domestica* L.) and peach seedling (*P. persica* L.) were grafted on a scion of 'Redhaven', the yellow-flesh peach cultivar acknowledged as the standard cultivar in Slovenia. According to Hudina et al. (2009), Ishtara and Tetra rootstocks generate the weakest growth; Adesoto, Julior, GF 677, MrS 2/5, Penta and peach seedling produce semi-vigourous growth, while Monegro, Barrier 1 and Cadaman result in vigourous growth. The trial was performed during 2008 at the Fruit Centre in Bilje near Nova Gorica (N 450 53.528; E 0130 38.606), Slovenia. The rootstocks were planted in a permanent place in spring 2005, with 4 × 2 m tree spacing. In August 2005, the 'Redhaven' cultivar was grafted on rootstocks and trained to a free spindle. The experiment was set up in replant soil, which had supported a previous peach orchard until 2004. A total of 15 trees were grafted on each rootstock. The trees were irrigated and hail net was used to protect them from bad weather. The orchard was managed according to standard integrated pest management (Ministry of Agriculture, Forestry and Food, 2007).

2.2. Determination of quality parameters

At harvest (2008 July 23 – 121 DAFB), 15 fruit, of the 'Redhaven' cultivar from each rootstock were randomly collected. Qualitative parameters of each fruit were evaluated in the lab at room temperature, 24 °C. The fruit were weighed using a precision scale at 0.01 g confidence level. Ground colour was determined with a Minolta colorimeter (Model CR 300 Croma Minolta camera Co., Osaka, Japan), where the parameters *L* (luminosity), *a* (green–red) and *b* (blue–yellow) were noted; however, only the "*a*" value is presented in the results, since according to Delwiche and Baumgardner (1983), differences in ground colour for varying maturities occur primarily in the "*a*" coordinate. On each fruit, skin was removed on four different sides and flesh firmness (FF) was measured using a digital penetrometer with an 8 mm tip. For determination of the soluble solids content (SSC) of each peach fruit, pulp was crushed and intact juice was immediately analysed using a digital refractometer, model WM-7 (Atago, Tokyo, Japan). After the qualitative parameter measurements, the fruit were grouped into samples of three. Each fruit was stoned. For extraction of sugars and organic acids unpeeled fruit were used whereas for all other chemical analyses fruit were peeled and skin and pulp were separately packed in paper bags. The tissues were kept at −20 °C until extraction.

2.3. Sugars and organic acids analysis

Ten grams of sample were brought to 40 ml of total volume with twice-distilled water and homogenised for one min at 24 °C with T-25 Ultra-Turrax (IKA® – Labortechnik, Staufen, Germany). Samples were left to extract for half an hour at 24 °C and centrifuged at 10,000 rpm for 7 min at 5 °C (Eppendort 5810 R Centrifuge, Hamburg, Germany). The supernatant was used for analysis after filtration through a 0.45-μm cellulose filter (Macherey – Nagel, Düren, Germany) into vials. Samples were analysed for individual sugar content (sucrose, glucose, fructose, and sorbitol) using a Thermo Separation Products high performance liquid chromatography (HPLC) with a refractive index (RI) detector (Thermo Scientific, Waltham, MA). The mobile phase (isocratic system) was twice-distilled water. For the separation of sugars, Razex RCM – monosaccharide column (300 × 7.8 mm; Phenomenex, Torrance, CA) was used, with temperature maintained at 65 °C at a flow rate of 0.6 ml min^{-1}. The method described by Dolenc and Stampar (1997) was used. All individual sugar content levels were expressed in g kg^{-1} of fresh weight (FW).

Analysis of individual organic acid (malic acid, citric acid, shikimic acid and fumaric acid) content was performed by the same equipment differing in column (HPX 87H, 300 × 7.8 mm; Bio-Rad, USA) was kept at 65 °C. The mobile phase (isocratic system) was 4 mM H_2SO_4 aqueous solution. The flow rate of the mobile phase was 0.6 ml min^{-1}. Ultraviolet detector was set at 210 nm. The method described by Dolenc and Stampar (1997) was used. Malic and citric acid content levels were expressed in g kg^{-1} of FW; shikimic and fumaric acid concentrations were expressed in mg kg^{-1} of FW. We used values of total sugar content and total organic acid content to calculate the sugar/organic acid ratio.

2.4. Extraction and analysis of total phenolics content

In extraction of total phenolics, 10 g of pulp or 5 g of skin were homogenised with 10 ml of methanol in an ultrasonic ice bath for 1 h and centrifuged at 10,000 rpm for 7 min at 5 °C. The supernatant was filtered through a Chromafil AO-45/25 polyamide filter (Macherey–Nagel, Düren, Germany) into a vial. The Folin–Ciocalteu phenol reagent method was used (Singleton & Rossi, 1965). The sample (100 μl) was added to 6 ml of twice-distilled water and 500 μl of Folin–Ciocalteu reagent. After 8 s to 8 min at room temperature (24 °C), 1.5 μl of sodium carbonate (20% w/v) was added. After mixing, the extract solution was kept at 40 °C for 30 min. Absorbance at 765 nm was measured on a Lambda Bio 20 UV/Vis spectrophotometer (Perkin–Elmer, Waltham, MA) and compared to a blank sample (100 μl of twice-distilled water was added instead of a sample). The total phenolic content was expressed as gallic acid equivalents (mg GAE kg^{-1} of FW).

2.5. Antioxidant capacity determination

The extraction of our tissues for determination of antioxidant activity was performed by the same procedure as described for the total phenolic content. We used the modified method described by Brand-Williams, Cuvelier, and Berset (1995). The free radical scavenging activity of peach tissues was measured by the use of DPPH (1,1-diphenyl-2-picrylhydrazyl). Samples (50 µl) were placed in three repetitions in 96-well microplates, and 200 µl of 0.1-mM methanolic solution of DPPH was added. We measured the decrease in absorbance of DPPH at 520 nm at starting point (at 0 min) and at stabilization of absorbance (at 30 min), using a spectrophotometer from MRX Dynex Technologies (USA). Methanol was used as a blank solution. The free radical scavenging activity of our samples was expressed as ascorbic acid equivalents (mg AAE kg^{-1} of FW), using ascorbic acid standard curves (Leong & Shui, 2002).

2.6. Individual phenolic compounds extraction and analysis

Extraction of individual phenolic compounds consisted of 10 g of pulp or 5 g of skin, which was homogenised with a 10 ml extraction solution (methanol containing 3% formic acid and 1% – 2,6-di-tert-butyl-4-methylphenol – BHT to prevent degradation of the phenolic compounds) in an ultrasonic ice bath for 1 h before centrifuging at 10,000 rpm for 7 min at 5 °C. The supernatant was filtered through the Chromafil AO-45/25 polyamide filter, (Macherey–Nagel, Düren, Germany) into a vial before analysis with a Surveyor HPLC system and a diode array detector (DAD), controlled by a Crom-Quest 4.0 chromatography workstation software system (Thermo Scientific, San Jose, CA). Phenomenex Gemini C18 (150 × 4.6 mm 3 µm; Phenomenex, Torrence, CA) column maintained at 25 °C was used. According to Bakhshi and Arakawa (2006) the phenolic compounds (chlorogenic acid, neochlorogenic acid, catechin, epicatechin, *p*-coumaric acid, caffeic acid and ferulic acid) were analysed at 280 nm, flavonols (quercetin 3-galactoside, quercetin 3-rutinoside, quercetin 3-glucoside, and quercetin 3-rhamnoside) were analysed in the skin at 350 nm, and anthocyanins (cyanidin 3-glucoside and cyanidin 3-rutinoside) were analysed at 530 nm and identified by their retention times and the use of external standards. The elution solvents used were these: 1% formic acid in twice-distilled water (A) and 99.8% acetonitrile (B) maintained at 1 ml min^{-1} using the linear gradient method described by Marks, Mullen, and Croizer (2007): 0–5 min, 3–9% B; 5–15 min, 9–16% B; 15–45 min, 16–50% B; 45–50 min, 50% isocratic; and finally washing and reconditioning of the column. Concentrations of all individual phenolic compounds were expressed in mg kg^{-1} of FW.

2.7. Chemicals

For quantification of individual sugars, fructose, glucose, sucrose and sorbitol were obtained from Fluka (Buchs, Switzerland). Malic acid was purchased from Merck (Darmstadt, Germany), citric, fumaric and shikimic acids were purchased from Fluka (Buchs, Switzerland) to quantify organic acids. The following standards were used for quantification of single phenolic compounds: chlorogenic acid (5-caffeoylquinic acid) from Sigma (St. Louis, MO, USA), caffeic acid, ferulic acid, (−)-epicatechin and *p*-coumaric acid from Fluka (Buchs, Switzerland) and (+)-catechin from Roth (Karlsruhe, Germany). For quantification of flavonols, rutin (quercetin 3-O-rutinoside) was obtained from Sigma (St. Louis, MO, USA), and quercetin 3-O-rhamnoside, quercetin 3-glucoside and quercetin 3-galactoside from Fluka. To quantify anthocyanins, cyanidin 3-glucoside and cyanidin 3-rutinoside were purchased from Sigma–Aldrich (Steinheim, Germany). Methanol was acquired from Sigma. Water was twice-distilled and purified with the Milli-Q system (Millipore, Bedford, MA, USA). For the total phenolic content, Folin–Ciocalteu reagent (Fluka), sodium carbonate (Merck) and gallic acid (Sigma) were used. For the antioxidant capacity 1,1-diphenyl-2-picrylhydrazyl (DPPH) and methanol were purchased from Sigma. Ascorbic acid was purchased from Fluka.

2.8. Statistical analysis

Statistical analysis was conducted using the Statgraphics Plus 5.1 program (Statgraphics, Herdon, VA). The data were subjected to one-way analysis of variance with rootstock as the variable factor. Differences between the means were estimated with the use of Duncan's test ($p < 0.05$).

3. Results and discussion

3.1. The effect of rootstocks on yield and quality parameters

Yield per tree, fruit weight, flesh firmness (FF), soluble solids content (SSC) and basic skin colour differed significantly among rootstocks (Table 1). Peach seedling produced the lowest total yield (12.92 kg $tree^{-1}$) that did not differ significantly among Monegro, GF 677, Tetra, Julior and Isthara. Barrier 1, Adesoto and MrS 2/5 produced biggest total yield reaching over 20 kg $tree^{-1}$. The GF 677 and Barrier 1 rootstocks produced the lightest fruit, while ‘Redhaven’ fruit harvested from Julior rootstock were found to be the heaviest, weighing up to 192 g per fruit; this contradicts the results from Massai and Loreti (2004), who reported Julior rootstock as generating fruit lower in weight. FF was also influenced by rootstock. Julior and Tetra produced the softest fruit, which could not be used for storage. In contrast, ‘Redhaven’ fruit from the Monegro rootstock were by far the firmest, followed by Barrier 1 rootstock fruit. SSC reached significantly the highest values in the Adesoto and Tetra rootstock fruit. Several rootstocks (Monegro, Barrier 1, Cadaman, MrS 2/5, Penta and peach seedling) generated low SSC.

Table 1
Yield per tree, fruit weight, flesh firmness (FF), soluble solids content (SSC), basic skin colour (“*a*” value) ± standard error in peach fruit from ‘Redhaven’ grafted on 11 different rootstocks.

Rootstocks	Yield (kg $tree^{-1}$)	Fruit weight (g)	FF (kg cm^{-2})	SSC (°Brix)	Basic skin colour (“*a*” value)
Adesoto	20.40 ± 1.3cd	145.2 ± 6.1bc	0.60 ± 0.06ab	10.6 ± 0.20d	19.0 ± 1.0f
Julior	16.54 ± 2.1abcd	158.4 ± 5.9c	0.47 ± 0.03a	10.2 ± 0.25cd	19.0 ± 1.7f
GF 677	15.19 ± 1.5abc	125.1 ± 4.0a	0.95 ± 0.10cd	9.9 ± 0.21bc	8.5 ± 1.1abc
Monegro	13.50 ± 1.5ab	141.0 ± 4.4b	4.17 ± 0.08e	8.7 ± 0.17a	13.5 ± 1.0de
Barrier 1	20.14 ± 1.6cd	124.0 ± 4.4a	1.12 ± 0.23d	9.2 ± 0.29a	8.2 ± 1.1ab
Cadaman	19.08 ± 2.2bcd	144.0 ± 5.7bc	0.94 ± 0.11cd	9.0 ± 0.22a	7.0 ± 1.3a
MrS 2/5	21.20 ± 1.1d	151.2 ± 5.8bc	0.71 ± 0.11abc	9.1 ± 0.21a	10.9 ± 0.9bcd
Ishtara	17.1 ± 2.1abcd	154.8 ± 4.0bc	0.64 ± 0.04ab	10.3 ± 0.17cd	12.0 ± 1.3cd
Penta	18.89 ± 1.5cd	144.0 ± 3.5bc	0.62 ± 0.04ab	9.2 ± 0.22a	16.8 ± 0.6ef
Tetra	15.37 ± 2.5abc	152.9 ± 6.4bc	0.55 ± 0.04a	10.6 ± 0.19d	15.5 ± 1.4ef
Peach seedling	12.92 ± 1.5a	156.2 ± 4.6bc	0.87 ± 0.13bcd	9.4 ± 0.19ab	11.6 ± 1.1bcd

Means within columns followed by the same letters are not significantly different ($p < 0.05$).

For both FF and SSC, Monegro and Barrier 1 rootstocks induced delayed maturity. Remorini et al. (2008) also reported that Barrier 1 delayed maturity, which is in accordance with our results. MrS 2/5 and Penta rootstocks resulted in low SSC, despite the softness of their fruit.

Skin colour is considered an important ripeness parameter, since the reference spectrum has been proposed as a ripeness index (Albás et al., 2004). The ground colour of peach fruit correlates to the FF of fresh market peaches. Differences in ground colour for the varying maturity occur in the "*a*" (green–red) coordinate, which increases as maturity advances (Delwiche & Baumgardner, 1983). We measured the highest "*a*" values on fruit from the Adesoto, Julior, Penta and Tetra rootstocks, indicating the ripest ones. Low "*a*" values were found in fruit collected from GF 677, Barrier 1 and Cadaman rootstocks. Surprisingly, high "*a*" values were noted for Monegro rootstock fruit, since FF and SSC both indicate lower ripeness of 'Redhaven' fruit. According to these quality parameters, rootstock does affect the maturation of 'Redhaven' fruit, which confirms the findings of Beckman et al. (1992).

3.2. The effect of rootstocks on sugars and organic acids

According to Byrne, Nikolic, and Burns (1991), Colaric (2002), Colaric et al. (2005) and Génard and Souty (1996), sucrose is the major sugar in peach fruit, followed by fructose and glucose. Byrne et al. (1991) also report that the ratio between fructose and glucose at technological maturity is about 2:1. In our experiment, we found sucrose to be the dominant sugar, ranging from 74% to 80% (from 78 g kg^{-1} FW to 96 g kg^{-1} FW) of total sugar content. The ratio between fructose and glucose was about 1:1. Glucose and fructose each represented from 9% to 15% (from 8.5 g kg^{-1} FW to 17.8 g kg^{-1} FW) of the total sugars. Our results are in accordance with Génard and Souty (1996), who report fructose and glucose to be present in equimolar quantities. They also state that glucose and fructose can be interconverted, thus potentially reducing or enhancing the differences between these sugars. Sorbitol was a minor sugar in peach fruit reaching content levels from 0.5 g kg^{-1} FW to 1.2 g kg^{-1} FW, which represents a range from 0.5% to 1.1% of total sugars. This confirms the statement by Génard and Souty (1996) that sorbitol content levels in peach fruit are always present in low quantities, reaching similar values to those reported by Colaric (2002).

We found significant differences in individual sugars and total sugar content among the fruit from trees grafted on different rootstocks (Fig. 1A). We measured the highest content of sucrose in 'Redhaven' fruit from Adesoto rootstock, which differed significantly from the content in 'Redhaven' fruit from Cadaman and MrS 2/5 trees, which produced the lowest sucrose content. Fruit from Julior had significantly the highest content of glucose, followed by fruit from Cadaman and Tetra. MrS 2/5 grafted trees produced fruit with the lowest glucose content. We found the highest content of fructose in 'Redhaven' fruit from Julior and Monegro, while fruit from Cadaman and MrS 2/5 rootstocks had the lowest fructose content. Significantly the highest content of sorbitol was measured in fruit from Monegro rootstock. According to Génard and Souty (1996), high values of sorbitol are present in fruit at

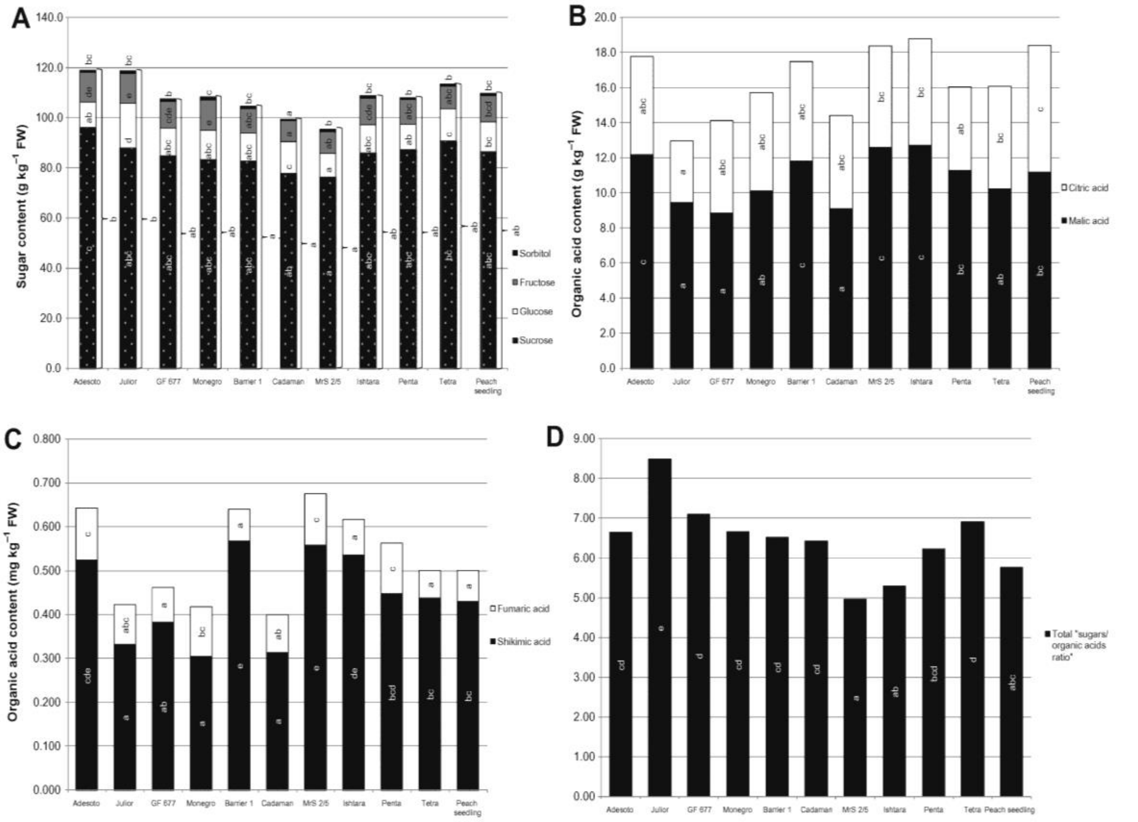

Fig. 1. Individual sugar content (A – sucrose, glucose, fructose and sorbitol and total sugars), acid content (B – malic and citric acids; and C – shikimic and fumaric acids) determined by HPLC and total "sugar/organic acids ratio" (D) in 'Redhaven' peach fruit grafted on 11 different rootstocks. Means followed by the same letters are not significantly different ($p < 0.05$).

early stages of development and decline to lowest values at ripeness, which further confirms our finding that the Monegro rootstock delays fruit maturity. Lower values were found in fruit on GF 677, MrS 2/5, Penta and Tetra rootstocks. Fruit from Cadaman rootstock had the lowest content of sorbitol. Total sugar content only differed between fruit from trees grafted on Adesoto and Julior, which had high content levels, and Cadaman and MrS 2/5, which had low content levels of total sugars.

Malic acid was found to be the main organic acid (Fig. 1B), representing from 59% to 81% (from 8.9 g kg^{-1} FW to 12.7 g kg^{-1} FW) of total organic acids in 'Redhaven' fruit. The second important organic acid in peach fruit is citric acid (Fig. 1B), which was present in a range from 3.5 g kg^{-1} FW to 7.2 g kg^{-1} FW. This represents 27–38% of total organic acids. Shikimic acid (from 305 mg kg^{-1} FW to 558 mg kg^{-1} FW) and fumaric acid (from 62 mg kg^{-1} FW to 118 mg kg^{-1} FW) (Fig. 1C) combined represent about 4% of total organic acids. Byrne et al. (1991), Colaric (2002) and Colaric et al. (2005) reported similar content levels for malic and citric acids. Shikimic and fumaric acids are also in accordance with Colaric (2002). Byrne et al. (1991) also report quinic acid to be present in peach fruit to a similar extent as citric acid; however, it was not identified by our method.

We found significant differences between our rootstocks in all the organic acids analysed. The highest level of malic acid was measured in 'Redhaven' fruit from Adesoto, Barrier 1, MrS 2/5 and Ishtara rootstocks. Low levels of malic acid were recorded in fruit from trees on Julior, GF 677, Cadaman and Tetra. Regarding citric acid content, peach seedling had high content levels, while Julior had low levels. Analysis of shikimic acid showed high levels in fruit from Adesoto, Barrier 1, MrS 2/5 and Ishtara rootstocks. Low content levels of shikimic acid were found in 'Redhaven' fruit from Julior, Monegro, GF 677 and Cadaman trees. Fumaric acid content was also influenced by rootstock. Adesoto, Monegro, MrS 2/5 and Penta rootstocks yielded high content levels of fumaric acid, while low fumaric acid content levels were reported in fruits from the GF 677, Barrier 1, Ishtara, Tetra and peach seedling rootstocks. Total organic acids content (data not shown) was the highest in 'Redhaven' fruit from Adesoto, MrS 2/5, Ishtara and peach seedling rootstocks. Low total organic acid levels were found in 'Redhaven' fruit from the Julior and Cadaman rootstocks.

The total "sugars/organic acids ratio" was calculated to determine the influence of rootstock on taste (Fig. 1D). According to Colaric et al. (2005), the total "sugars/organic acids ratio" is positively correlated to sensory perception of sweetness. According to our results, 'Redhaven' fruit from Julior rootstock trees were by far the sweetest. High values of total sugars and low values of total individual acids led us to the conclusion that Julior rootstock may provoke precocity. We found similar values for the total "sugars/organic acids ratio" in 'Redhaven' fruit from the Adesoto, GF 677, Monegro, Barrier 1, Cadaman and Tetra rootstocks; however, considering total sugars and total organic acids content levels, we can observe the potential influence of individual rootstocks on the fruit's taste and its maturity. Adesoto rootstock had both high values of total sugars and high values of organic acids at full maturity of the fruit, which resulted in a lower sugars/organic acids ratio. The low total "sugars/organic acids ratio" of MrS 2/5 and Ishtara fruit is a consequence of low sugar and high organic acids content. MrS 2/5 and Ishtara rootstocks clearly influenced delayed maturity in the 'Redhaven' cultivar.

3.3. The effect of rootstocks on total phenolics and antioxidant capacity in flesh and skin of 'Redhaven' peach

Total phenolics content in skin and pulp was determined (Table 2). According to Gil et al. (2002), Leontowicz et al. (2002), Remorini et al. (2008), and Tomás-Barberán et al. (2001), higher content levels of total phenolics were found in the skin of fruit from all rootstocks. Values of total phenolics in pulp and in skin were about four times lower (from 52 mg kg^{-1} FW to 107 mg kg^{-1} FW and from 149 mg kg^{-1} FW to 356 mg kg^{-1} FW, respectively) than those reported by Gil et al. (2002). Total phenolics in pulp reached from 18% to 54% of skin values. The decrease in pulp phenolics content can be attributed to a series of chemical and enzymatic alternations of some of the phenolics during ripening (Remorini et al., 2008). Significant differences in both tissues were found between our rootstocks. Fruit from the Monegro rootstock had by far the highest content of total phenolics in the skin; however, there was also a low content level in the pulp. Fruit from Adesoto, Julior and MrS 2/5 also had high total phenolics content in skin as well as high levels in the pulp. Remorini et al. (2008) also reported the highest content of total phenolics in 'Flavorcrest' peach fruit from MrS 2/5 fruit on the first picking date. 'Redhaven' fruit from Penta, Barrier 1, Cadaman and peach seedling rootstocks had a high content of total phenolics in the pulp, but had a low level in the skin. Fruit from Ishtara rootstock had low level of total phenolics in skin and pulp. The rootstock, therefore, appears to influence the amount of total phenolics in skin and pulp.

The antioxidant capacity of skin was also higher than that of pulp. In general, fruit with higher total phenolic content showed high antioxidant capacity (Table 2). Gil et al. (2002) reached similar conclusions in a study comparing total phenolics and antioxidant capacity in pulp and in skin of different peach cultivars ('Redhaven' not included); however, they reported up to three times higher values of antioxidant capacity compared to ours. Significant differences in antioxidant capacity in both tissues were found between our rootstocks. We found the highest antioxidant capacity in 'Redhaven' pulp from Adesoto, Cadaman and peach seedling rootstocks, while fruit from the Ishtara rootstock had the lowest antioxidant

Table 2
Total phenolic content and antioxidant capacity ± standard error in pulp and skin of 'Redhaven' peach fruit grafted on 11 different rootstocks.

Rootstocks	Total phenols – pulp mg GAE kg^{-1} of FW	Total phenols – skin mg GAE kg^{-1} of FW	Antioxidant capacity – pulp mg AAE kg^{-1} of FW	Antioxidant capacity – skin mg AAE kg^{-1} of FW
Adesoto	88.21 ± 7.18c	304.40 ± 17.59de	21.05 ± 1.46b	41.54 ± 3.63b
Julior	76.69 ± 6.27bc	245.44 ± 27.22bcd	17.39 ± 0.73ab	32.88 ± 3.38ab
GF 677	67.43 ± 4.08ab	149.04 ± 10.27a	17.96 ± 0.44ab	32.82 ± 6.85ab
Monegro	64.31 ± 9.57ab	355.57 ± 34.76e	14.97 ± 0.67ab	39.38 ± 3.43b
Barrier 1	83.89 ± 5.60c	202.59 ± 19.07abc	18.28 ± 1.43ab	37.00 ± 1.61ab
Cadaman	89.73 ± 5.77c	159.35 ± 18.57a	21.39 ± 2.05b	35.02 ± 4.08ab
MrS 2/5	75.34 ± 2.46bc	243.86 ± 27.21bcd	16.35 ± 2.43ab	34.78 ± 1.46ab
Ishtara	51.97 ± 5.03a	180.70 ± 12.28ab	14.50 ± 1.01a	34.01 ± 3.01ab
Penta	106.95 ± 4.83d	197.92 ± 17.00abc	19.69 ± 1.72ab	36.56 ± 2.87ab
Tetra	64.61 ± 2.70ab	263.51 ± 10.98cd	14.73 ± 1.87ab	37.24 ± 2.22ab
Peach seedling	85.22 ± 4.02c	197.62 ± 24.80abc	20.82 ± 1.28b	26.02 ± 1.94a

Means within columns followed by the same letters are not significantly different ($p < 0.05$).

capacity in its pulp. High antioxidant capacity in the skin was measured in Adesoto and Monegro rootstock. Fruit from peach seedling rootstock had the lowest antioxidant capacity in the skin.

3.4. The effect of rootstocks on individual phenolics, flavonols and anthocyanins in flesh and skin of 'Redhaven' peach

Individual phenolics content levels were identified and quantified in pulp (neochlorogenic acid, chlorogenic acid, catechin, caffeic acid and ferulic acid, in this order) (Fig. 2A) and in skin (chlorogenic acid, neochlorogenic acid, epicatechin and *p*-coumaric acid, in this order) (Fig. 2A) with HPLC analysis. We found significant differences in the content of all phenolics among these rootstocks in both tissues. Tomás-Barberán et al. (2001) reported chlorogenic acid to be the major phenol in the pulp and skin of peach fruit, followed by neochlorogenic acid. They also found catechin, epicatechin and procyanidin B1 in the pulp and skin of several peach cultivars. The differences in the content of phenolics could be the result of a different cultivar, a different method of extraction and analysis (Tomás-Barberán et al., 2001), or even climatic conditions.

Fruit from Adesoto rootstock had the highest content of all phenolics determined, except for ferulic acid in the pulp. Tetra and MrS 2/5 rootstock fruit also had high content levels of phenolics measured in the pulp; however, they failed to match the neochlorogenic acid content of Adesoto rootstock. Penta rootstock fruit had levels of neochlorogenic acid similar to those of Tetra and MrS 2/5 in the pulp. Penta had lower levels of chlorogenic acid, catechin, caffeic acid and ferulic acid than 'Redhaven' fruit from Penta and MrS 2/5 rootstocks. Julior and peach seedling rootstocks resulted in low content levels of all phenolics except caffeic acid in 'Redhaven' fruit. The lowest content levels of all phenolics measured in the pulp were noted in GF 677 rootstock fruit.

The highest content levels of all individual phenolics measured in the skin were found in 'Redhaven' fruit from Monegro rootstock. Adesoto, GF 677, Ishtara and Tetra rootstock also reached content levels of phenolics in the skin comparable to those of Monegro rootstock fruit, except for *p*-coumaric acid content levels. 'Redhaven' fruit from MrS 2/5 and peach seedling rootstocks had low values of chlorogenic acid, neochlorogenic acid and *p*-coumaric acid in the skin; however they had high values of epicatechin. Cadaman rootstock generated low values of all phenolics in the skin.

Our analysis revealed a flavonol content similar of to that reported by Tomás-Barberán et al. (2001) in yellow-flesh peach cultivars (Table 3). They found quercetin 3-rutinoside to be the major flavonol, followed by quercetin 3-glucoside and quercetin 3-galactoside in the skin of peach fruit, and a similar order can be observed in our results. Monegro rootstock fruit contained the highest content of flavonols determined, followed by Julior, Ishtara, Adesoto, GF 677, Barrier 1, Tetra, Seedling, Penta, MrS 2/5, and Cadaman, which contained the lowest amount of flavonols. The high content levels in Monegro fruit could be explained by the ripeness of the fruit, since Tomás-Barberán et al. (2001) reported higher content levels of flavonols in mature (at harvest) fruit compared to the ripe fruit (ripened at 20 °C for 5 days after harvest) of several

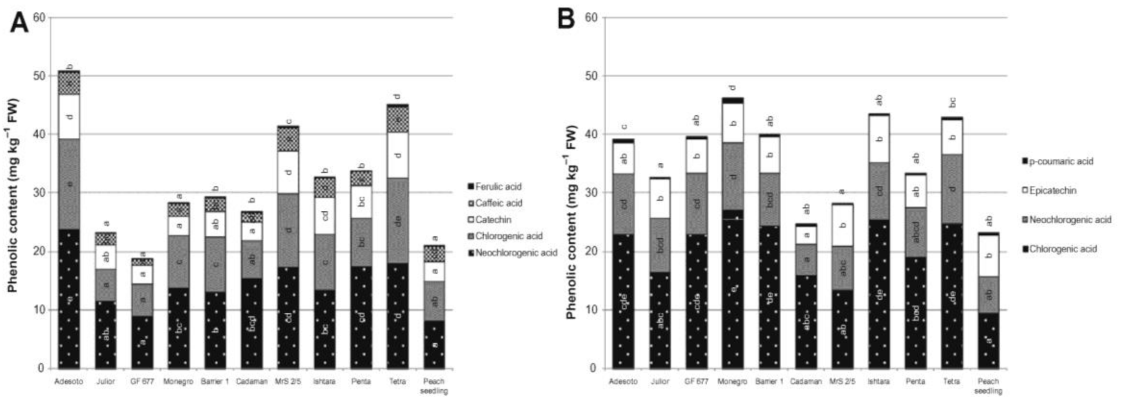

Fig. 2. Individual phenolic compounds content in pulp (A) and in skin (B) of 'Redhaven' peach fruit grafted on 11 different rootstocks. Means followed by the same letters are not significantly different ($p < 0.05$).

Table 3
Individual flavonols and anthocyanin content in skin ± standard error of 'Redhaven' peach fruit grafted on 11 different rootstocks.

Rootstocks	qu* 3-Galactoside mg kg^{-1} FW	qu* 3-Rutinoside mg kg^{-1} FW	qu* 3-Glucoside mg kg^{-1} FW	qu* 3-Rhamnoside mg kg^{-1} FW	cy** 3-Glucoside mg kg^{-1} FW	cy** 3-Rutinoside mg kg^{-1} FW
Adesoto	2.33 ± 0.28bcd	11.82 ± 0.70bcd	5.44 ± 0.43bc	1.16 ± 0.09cd	181.64 ± 13.96c	27.38 ± 3.00c
Julior	3.28 ± 0.02e	14.06 ± 3.42d	5.40 ± 1.73bc	1.41 ± 0.15de	131.37 ± 46.25abc	21.13 ± 8.49abc
GF 677	2.05 ± 0.17bcd	11.59 ± 1.52bcd	5.10 ± 0.87abc	1.07 ± 0.10bc	84.38 ± 15.29a	13.73 ± 2.72ab
Monegro	3.32 ± 0.42e	15.98 ± 1.63d	8.79 ± 1.05d	1.61 ± 0.17e	250.71 ± 41.04d	42.03 ± 5.94d
Barrier 1	1.83 ± 0.23abc	9.51 ± 0.66abc	4.41 ± 0.20abc	1.02 ± 0.02abc	113.26 ± 9.62ab	19.10 ± 0.89abc
Cadaman	1.21 ± 0.13a	5.83 ± 1.07a	2.69 ± 0.48a	0.70 ± 0.09a	72.26 ± 16.66a	11.66 ± 2.83a
MrS 2/5	2.61 ± 0.15de	6.92 ± 0.50a	4.12 ± 0.34abc	0.88 ± 0.07abc	150.50 ± 8.02bc	24.87 ± 1.24bc
Ishtara	2.69 ± 0.20de	13.01 ± 1.55cd	6.56 ± 0.81c	1.14 ± 0.12cd	172.91 ± 23.11bc	27.52 ± 4.09c
Penta	2.45 ± 0.25cd	7.77 ± 1.11ab	3.94 ± 0.52ab	0.80 ± 0.11ab	124.46 ± 12.27abc	19.74 ± 1.81abc
Tetra	1.62 ± 0.22ab	8.92 ± 1.59abc	4.27 ± 0.65abc	0.79 ± 0.10ab	116.07 ± 17.61ab	17.87 ± 2.87abc
Peach seedling	2.79 ± 0.11de	8.35 ± 0.65ab	4.61 ± 0.33abc	0.80 ± 0.09ab	122.36 ± 8.92abc	19.73 ± 1.86abc

Means within columns followed by the same letters are not significantly different ($p < 0.05$). qu* – quercetin and **cy – cyanidin.

cultivars. However, similar content levels were also found in Julior rootstock fruit (ripe fruit), indicating that the genetic origin of rootstock or a rootstock's vigour may influence flavonol content.

Anthocyanins were detected only in the skin reaching values similar (Table 3) to those reported by Tomás-Barberán et al. (2001). Cyanidin 3-glucoside was found to be the major anthocyanin, followed by cyanidin 3-rutinoside, which shows levels approximately six times lower. 'Redhaven' fruit from Monegro rootstock had the highest content of both anthocyanins, indicating less ripe fruit, which is in accordance with Tomás-Barberán et al. (2001), who reported higher anthocyanin concentration in fruit at earlier maturity stages in several yellow-flesh peach cultivars. The Adesoto rootstock fruit had the second highest content; however, it recorded only 73% of the Monegro value for anthocyanins. Cadaman rootstock generated the lowest values of both anthocyanins.

4. Conclusion

Our results indicate that rootstock influenced both the fruit quality and the chemical composition of peach fruit. Several conclusions can be drawn about the effects of the rootstocks studied. We have confirmed findings by Albás et al. (2004), Giorgi et al. (2005) and Hudina et al. (2006) that the rootstock has a significant impact on all quality parameters of the peach fruit. The most obvious effect of rootstocks was the influence on the duration of the ripening process. This was most evident in the case of Julior (precocity), on the one hand, and Monegro (delayed maturity) on the other, as well as in some other rootstocks (Barrier 1, Cadaman, and peach seedling), however to a lesser extent. Delayed maturity was reflected in low soluble solids content, low "*a*" values of basic colour and in low sugar content. All other rootstocks resulted in similar duration of fruit development, particularly with regard to flesh firmness and soluble solids content. It appears that Monegro rootstock influences the content of total phenolics, antioxidant potential, individual phenolics, flavonols and anthocyanin content in a similar way to that described by Tomás-Barberán et al. (2001), who reported higher content levels of these phytochemicals in less ripe peach fruit. Adesoto rootstock was found to produce excellent fruit quality, reaching high values of several parameters measured (individual sugar content and total sugars content, individual and organic acid content, phenolic content in pulp, antioxidant capacity in pulp and in skin), thus proving to be the best rootstock in terms of fruit quality among the ones tested. In addition Adesoto was also one of the most productive rootstocks. Cadaman, Barrier 1, GF 677, Penta and peach seedling rootstocks resulted in poor fruit quality. Some of the parameters indicated less ripe fruit (low soluble solids content, "*a*" value of basic colour, individual and total sugar content levels), thus providing at least a partial explanation for poor fruit quality; nevertheless, each of these rootstocks differently affected fruit quality under identical growing conditions, so we must conclude that the genetic origin of the rootstock defines a cultivar's fruit quality.

Our results are particularly important because the rootstocks were tested under replant orchard conditions. Several authors reported differences in adaptation to these conditions, resulting in higher tree mortality, reduced vigour, yield and fruit quality (Hudina et al., 2006; Layne, 1994; Massai & Loreti, 2004). We have established that several rootstocks in our experiment coped well with orchard replant conditions, producing fruit of excellent nutritional quality and health-promoting properties. Adesoto and Julior are the rootstocks showing greatest potential in Mediterranean weather conditions. Monegro rootstock, despite its effect on delayed maturity, also shows good potential – at least for additional studies. Further studies should involve more cultivars to establish if the rootstock's impact on fruit quality is always the same.

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2.2 KAKOVOST PLODOV SORT 'REDHAVEN' IN 'ROYAL GLORY' NA SEDMIH RAZLIČNIH PODLAGAH

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Fruit quality of Redhaven and Royal Glory peach cultivars of seven different rootstocks

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Pomološke in kemične lastnosti plodov so kazalnik zunanje in notranje kakovosti plodov. Znano je, da se med sadnimi vrstami in sortami te lastnosti razlikujejo. Na kakovost plodov pa lahko pomembno vpliva tudi izbira podlage. Predvidevali smo, da bodo podlage vplivale na kakovost plodov, hkrati pa smo z raziskavo želeli preveriti ali se ta vpliv med sortami razlikuje. V poskusu smo leta 2009 spremljali rast dreves, pridelek in kakovost plodov dveh sort breskve 'Redhaven' in 'Royal Glory', cepljenih na sedem različnih podlag. Podlage so bile 'Adesoto', 'Barrier 1', 'GF 677', 'Ishtara', 'Monegro', 'Penta' in sejanec. V tehnološki zrelosti posamezne sorte smo plodove obrali, opravili meritve pomoloških lastnosti ter s tekočinsko kromatografijo visoke ločljivosti (HPLC) analizirali vsebnosti primarnih in sekundarnih metabolitov.

Pri obeh sortah smo ugotovili podoben vpliv podlag na bujnost rasti dreves, vendar je bil pridelek pri sorti 'Redhaven' pri vseh podlagah značilno večji od pridelka sorte 'Royal Glory'. Pri analizah suhe snovi v plodovih smo pri posamezni sorti zabeležili različen odziv. Podlage pri sorti 'Redhaven' niso značilno vplivale na vsebnost suhe snovi v plodovih, medtem ko so bile pri sorti 'Royal Glory' pri tem parametru razlike statistično značilne. Vsebnosti večine primarnih (posamezni in skupni sladkorji, organske kisline) in sekundarnih metabolitov (fenolne snovi; kvercetini, antociani…) so se značilno razlikovale ne le med sortama, ampak tudi med podlagami pri posamezni sorti. Ugotovili smo, da so se fenolne kisline v mesu in kožici pri obeh sortah bolj spreminjale, kot so se spreminjali drugi sekundarni metaboliti.

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Fruit Quality of Redhaven and Royal Glory Peach Cultivars on Seven Different Rootstocks

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ABSTRACT: Two peach cultivars, Redhaven and Royal Glory, grafted on seven different rootstocks (Adesoto, Barrier 1, GF 677, Ishtara, Monegro, Penta, and peach seedling) were analyzed for tree vigor and yield. Fruit of similar ripeness (fruit firmness) was analyzed in terms of pomological (fruit weight, soluble solids content) and biochemical parameters (individual sugars, organic acids, phenolic acids in the flesh and peel, as well as flavonols and anthocyanins in the peel). A uniform effect of rootstock on tree size was evident in the cases of both cultivars. The Ishtara rootstock induced weak tree growth; Adesoto, Penta and peach seedling semivigorous growth; and Barrier 1, GF 677, and Monegro vigorous tree growth. We recorded higher yields in the Redhaven cultivar, while no significant differences in yield in the fourth growing season were found among the rootstocks for each cultivar. Rootstock had no effect on soluble solids in the Redhaven cultivar, while in the Royal Glory it did. Penta yielded the highest soluble solids content levels, while Adesoto and Monegro were associated with low levels. In the fruit from both cultivars, the rootstock had a significant influence on individual sugars, organic acids, and phenolic acids in the pulp. We also found that phenolic acids in the pulp and skin were more affected by the rootstock than other secondary metabolites analyzed, regardless of the cultivar.

KEYWORDS: *Prunus persica*, sugars, organic acids, phenolics, flavonols, anthocyanins

■ INTRODUCTION

The selection of an appropriate rootstock is important for any orchard. Production of peach orchards, particularly replanted ones, greatly depends on the selection of the right rootstock. Various species and interspecific hybrids can be used as a peach rootstock.[1] Several aspects are considered in rootstock breeding: vigor,[1−11] adaptation to various soil types[12] and water conditions,[13] biotic stress, compatibility with the selected cultivar, and tolerance to replant soil conditions.[14−16] It has been confirmed that rootstocks of different genetic origin adapt differently to replant conditions. Peach was proven to grow normally after any fruit tree, except after grapevine. A retarded growth of peach trees was reported when these were planted after *Prunus persica* (L.) Batsch.[14] On the other hand, *Prunus domestica* L. trees thrive well when planted after any fruit species, except after peach.[16] The factors influencing replanting problems can be divided into specific and nonspecific replant diseases. Poor growth of trees planted in soil after the same species or after a different species of the same genus can be attributed to specific replant diseases.[15] Therefore, the genetic origin of the rootstock in the previous orchard is also relevant for rootstock selection in the current orchard. The first generations of peach orchards in Slovenia are grafted on peach seedling, while for the second generation, the GF 677 rootstock was used. For most of the surveyed peach growers in Slovenia, the third replantation of peach orchards will take place in the near future. Specific adaptation of rootstocks of different genetic origins to replant conditions led us to include rootstocks of various origin that showed good potential in other regions.

In addition to various abilities of rootstocks to adapt to specific growing conditions, a significant effect of the rootstock on sweet cherry[17] and peach fruit quality has been established by several authors.[2,5,8,18,19] Rootstocks of similar vigor yet of different genetic origin can produce peach fruit of different quality, indicating that vigor is not the only parameter affected by the rootstock.[5,8,17] Sugars and organic acids are affected by the rootstocks[8,9,17] and the levels of primary metabolites define taste.[20] Phenolic compounds in fruit play an important role in several quality characteristics, for example, taste, coloration, and health-promoting properties.[21] Minor effect of three rootstocks of similar genetic origin on antioxidant capacity of peaches was evident in the study of Dragouldi and Tsipouridis.[22] The effect of nine cultivars on quality characteristics and nutritional attributes including total phenolics, antioxidant capacity, and ascorbic acid was previously studied[22] and significant differences were found. Scalzo et al.[23] found differences in antioxidant capacity in the fruit of the Suncrest peach cultivar grafted on different rootstocks. Tavarini et al.[13] studied the effect of water stress and rootstock on quality indices and nutritional characteristics of Suncrest peach cultivar. They found that water management has a significant effect on quality parameters and phytochemical compounds in peach fruit and that each rootstock responded differently to water stress. Little is known of the effect of rootstock on phenolics composition, and our study will provide additional information on whether a similar response of a rootstock is expected when grafted with a different cultivar in terms of fruit quality.

The aim of this study was to continue an earlier study where we compared the effect of 11 rootstocks on the fruit quality of the Redhaven cultivar.[8] We will present the influence of seven rootstocks grafted with the Royal Glory and Redhaven peach cultivars on tree vigor, yield, and quality parameters. We will also establish to what extent the selection of the cultivar and rootstock affects fruit quality. A comparison of tree vigor, yield, crop load,

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Table 1. Rootstocks Used in the Present Study

rootstock	genetic origin	ref
Adesoto	*Prunus insititia* L.	Moreno et al.[41]
Barrier 1	*P. persica* × *Prunus davidiana* L.	Remorini et al.[9]
GF 677	*Prunus amygdalus* × *P. persica*	Bernhard and Grasselly[42]
Ishtara	(*Prunus cerasifera* × *Prunus salicina*) × (*Prunus cerasifera* × *P. persica*)	Renaud et al.[43]
Monegro	*P. amygdalus* Batsch. × *P. persica*	Felipe[44]
Penta	*P. domestica*	Nicotra and Moser[45]
Peach seedling	*P. persica*	Byrne[12]

yield efficiency, and fruit quality will tell us whether the effect of the selected rootstocks is consistent in combination with different cultivars. Significant seasonal influence on quality parameters of various stone fruit[24,25] leads us to include single-season results.

MATERIALS AND METHODS

Plant Material and Experimental Design. 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. All measurements presented in this paper were conducted in 2009. Two yellow-flesh cultivars, Royal Glory and Redhaven, were studied, each in combination with seven rootstocks: Adesoto, Barrier 1, GF 677, Ishtara, Monegro, Penta, and peach seedling. The genetic origin of each rootstock is presented in Table 1. The field used in our experiment had previously supported two generations of peach orchard.

Two nearby fields were selected for the study. The first one was assigned to the Redhaven and the second one to the Royal Glory cultivar. Twelve trees of each rootstock were randomly distributed in groups of three in a randomized block design. The rootstocks were planted in a permanent place in spring 2005 with 4 × 2 m tree spacing. Grafting was performed in August 2005. We trained the trees to a free spindle.[26] Uniform thinning was applied to all the trees in early May (stone hardening period), leaving approximately 6 cm between the remaining fruit. The whole orchard was managed according to the standard integrated pest management.

Description of the Treatments and Data Collection. The circumference of each tree was measured in spring and autumn 2009. For each cultivar, peaches were harvested four times, 3 days apart. At each picking time, all ripe fruit from each tree were harvested. The first harvest of the Royal Glory was completed on July 6 [102 days after full bloom (DAFB)] and the first harvest of the Redhaven was on July 16 (112 DAFB); peaches from all the trees were picked at once on the basis of similar maturity (fruit firmness). At each picking all the ripe fruit from each tree were counted and weighed to determine total yield per tree (kg/tree) and crop load (number of fruit/cm^2 TCSA). Yield efficiency was calculated using the total yield to autumn trunk cross-sectional area (TCSA) ratio. The fruit from the first harvest were assorted according to their cultivar/rootstock combination. Fifteen randomly selected fruit from each cultivar/rootstock were transported to the laboratory facilities for further quality analysis. All quality analyses and extractions were made at room temperature (24 °C). Each fruit was weighed on a precision scale to 0.01 g confidence level. From each fruit, the skin was removed on four sides, and fruit firmness was measured four times using a digital penetrometer (TR, Turini, Italy) with an 8 mm tip. In order to determine the soluble solids content (SSC), the pulp from each fruit was crushed and the intact juice was immediately analyzed with a digital refractometer (model WM-7, Atago, Tokyo, Japan).

For further analysis, 15 fruit were randomly distributed into five groups of three fruit. Each fruit was halved and pitted. For extraction of sugars and organic acids, the unpeeled half of each fruit was used, while for individual phenolics the half was peeled, and the skin and the pulp were kept separate. All tissues were frozen immediately and kept at −20 °C until extraction. Concentration of all analyzed chemical compounds was expressed as per fresh weight (FW).

Sugars and Organic Acids Extraction and Analysis. An identical method of extraction was used to extract sugars and organic acids and was previously described by Orazem et al.[8] Three unpeeled halves were ground and 10 g of fruit was brought to a volume of 40 mL using twice distilled water. Samples were homogenized using the T-25 Ultra-Turrax (IKA-Labortechnik, Staufen, Germany) and then left for 0.5 h at room temperature (24 °C) to extract, centrifuged at 10 000 rpm for 7 min at 5 °C, and filtered through a 0.45 μm cellulose filter (Macherey-Nagel, Düren, Germany). The content of individual sugars (sucrose, glucose, fructose, and sorbitol) and individual organic acids (citric, malic, shikimic, and fumaric acids) was determined by high-performance liquid chromatography (HPLC) (Thermo Separation Products, Waltham, MA).

Individual sugars were detected with a refractive index (RI) detector after separation with a Razerex RCM-monosaccharide column (300 × 7.8 mm; Phenomenex, Torrance, CA) kept at 60 °C. The samples were eluted according to the isocratic method.[27] The elution solvent was twice distilled water at a flow rate maintained at 0.6 mL/min.

Organic acids were detected with an ultraviolet UV detector (Knauer, Berlin, Germany) set at 210 nm after separation with HPX 87H, 300 × 7.8 mm (Bio-Rad, Hercules, CA) kept at 60 °C.[27] The elution solvent was 0.4 mmol sulfuric acid diluted with twice distilled water at a flow rate maintained at 0.6 mL/min.

The identification of both sugars and organic acids was made by comparing the retention time (sucrose, 9.5 min; glucose, 11.3 min; fructose, 14.3 min; sorbitol, 23.4 min; malic acid, 10.9 min; citric acid, 8.9 min; shikimic acid, 12.5 min; fumaric acids, 13.5 min) for each peak with those for the corresponding standard, and the concentration was calculated using an external standard. Individual sugars and malic and citric acid contents were expressed in g/kg (FW), while shikimic and fumaric acids were expressed in mg/kg FW.

Extraction of Phenolic Acids, Flavonols, and Anthocyanins and HPLC Analysis. The extraction of individual phenolic acids, flavonols, and anthocyanins was performed according to the modified method.[28] The skin or the pulp from three fruit was ground and 5 g of skin or 10 g of pulp was homogenized with 10 mL of extraction solution, which consisted of methanol containing 3% formic acid and 1% of 2,6-di-*tert*-butyl-4-methylphenol (BHT) using an ultrasonic bath for 1 h. Samples were centrifuged at 10 000 rpm for 7 min at 5 °C, and the supernatant was filtered through the Chromafil AO-45/25 polyamide filter (Macherey-Nagel, Düren, Germany) into a vial. HPLC analysis was preformed with the Surveyor system with a diode array detector (DAD), controlled by a Crom-Quest 4.0 chromatography workstation software system (Thermo Finigan, San Jose, CA). The column used for the separation was a Gemini C_{18} (150 × 4.6 mm; Phenomenex, Torrance, CA) maintained at 25 °C. Phenolic acids (neochlorogenic, chlorogenic, and *p*-coumaric acid) were analyzed at 280 nm at retention times of 8.5, 12.2, and 21.3 min, respectively, flavonols at 350 nm (quercetin 3-galactoside, quercetin 3-glucoside, quercetin 3-rutinoside, and quercetin 3-rhamnoside) at retention times 25.4, 25.53, 27.7, and 24.8 min, respectively, and anthocyanins at 530 nm (cyanidin 3-glucoside and cyanidin 3-rutinoside) at retention times of 12.0 and 12.8 min, respectively.[29] The elution solvents were 1% aqueous formic acid (A) and 100% acetonitrile (B) at a flow rate maintained at 1 mL/min. The gradient method was used.[30] All phenolic acids, flavonols, and anthocyanins presented in our results were identified with a HPLC-Finnigan MS detector and an LCQ Deca XP MAX (Thermo Finigan, San Jose, CA) instrument with electrospray interface (ESI) operating in negative ion mode. The analyses were performed using full-scan data dependent MS^n scanning from m/z 115 to 2000. Column and chromatographic

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Table 2. Average Trunk Circumference (cm), Yield (kg/tree), Crop Load (number of fruit/cm^2), Yield Efficiency (kg/cm^2), Soluble Solids Content (SSC, °Bx), and Fruit Weight (g) of Redhaven and Royal Glory on Different Rootstocks[a]

cultivar	rootstock	trunk circumference	yield	crop load	yield efficiency	SSC	weight
Redhaven	Adesoto	23.3 ± 0.7 b	27.2 ± 1.4	3.6 ± 0.3 b	0.6 ± 0.06 bc	9.3 ± 0.22	161.6 ± 3.4 ab
	Barrier 1	25.5 ± 0.7 c	29.2 ± 2.2	3.6 ± 0.2 b	0.6 ± 0.03 abc	9.8 ± 0.29	170.1 ± 5.6 b
	GF 677	25.9 ± 0.7 c	29.0 ± 1.5	3.5 ± 0.3 b	0.6 ± 0.05 ab	9.2 ± 0.14	156.6 ± 3.3 a
	Ishtara	18.0 ± 0.7 a	26.7 ± 1.7	6.7 ± 0.4 d	1.0 ± 0.05 e	9.2 ± 0.24	156.7 ± 2.6 a
	Monegro	28.9 ± 0.7 d	30.7 ± 2.7	1.9 ± 0.3 a	0.4 ± 0.05 a	9.6 ± 0.33	171.5 ± 3.3 b
	Penta	21.7 ± 0.6 b	28.8 ± 1.0	5.0 ± 0.2 c	0.8 ± 0.04 d	9.2 ± 0.25	152.3 ± 3.3 a
	Peach seedling	22.3 ± 0.5 b	26.6 ± 1.3	4.2 ± 0.4 bc	0.7 ± 0.03 cd	8.9 ± 0.18	161.4 ± 5.1 ab
Royal Glory	Adesoto	25.0 ± 1.5 b	15.0 ± 1.8	2.2 ± 0.3 a	0.3 ± 0.06 ab	9.0 ± 0.21 a	162.3 ± 6.6 ab
	Barrier 1	27.7 ± 1.1 c	18.5 ± 1.3	2.0 ± 0.2 a	0.3 ± 0.03 ab	9.2 ± 0.25 ab	147.7 ± 4.6 a
	GF 677	29.0 ± 0.7 c	16.4 ± 0.7	1.6 ± 0.1 a	0.2 ± 0.02 a	9.7 ± 0.13 bc	156.6 ± 5.1 ab
	Ishtara	19.7 ± 0.7 a	18.1 ± 1.0	4.0 ± 0.3 c	0.6 ± 0.04 d	9.6 ± 0.15 bc	148.1 ± 6.6 a
	Monegro	30.0 ± 1.4 c	14.9 ± 0.9	1.6 ± 0.2 a	0.2 ± 0.03 a	8.8 ± 0.15 a	160.3 ± 7.1 ab
	Penta	23.8 ± 0.5 b	17.1 ± 1.0	2.2 ± 0.2 a	0.4 ± 0.03 bc	10.0 ± 0.15 c	173.8 ± 4.1 b
	Peach seedling	23.3 ± 1.1 b	18.3 ± 1.0	3.1 ± 0.3 b	0.5 ± 0.03 c	9.59 ± 0.24 bc	161.0 ± 4.4 ab

[a] Average values ± standard errors are presented. Different letters in columns for each cultivar indicate significantly different values at $p < 0.05$.

conditions were identical to those used for the HPLC-DAD analyses. Quantification of individual phenolic compounds was achieved according to concentrations of corresponding external standard and expressed in mg/kg of FW.

Statistical Analysis. The data were analyzed using the Statgraphics Centurion XV (Statgraphics, Herdon, VA). Two-way analysis of variance (MANOVA) was used to determine the effect of the rootstocks, cultivar, and their interaction on pomological and biochemical properties at a significance level of 0.05. One-way analysis of variance (ANOVA) was used to determine the influence of the rootstocks on various quality parameters for each cultivar. Differences among the rootstocks were tested with the Duncan test at a significance level of 0.05.

■ RESULTS AND DISCUSSION

Tree Size. In combination with Royal Glory all rootstocks produced significantly bigger trunk circumferences compared to Redhaven, indicating that the cultivar affects tree vigor. Differences in trunk circumference among the rootstocks were also statistically significant (Table 7), which is in accordance with previous publications.[2,3,5,10,11,31,32] There was no significant interaction between rootstock and cultivar (Table 6); hence, a similar ranking of rootstocks according to circumference was found for both cultivars (Table 2). Similar results for rootstock influence on tree vigor have been reported previously; however, these were in combination with a different cultivar.[9] Ishtara induced the smallest trunk circumferences by far in both cultivars. Bigger trunk circumferences were characteristic for Adesoto, Penta, and peach seedling rootstocks. Barrier, GF 677, and Monegro rootstocks induced significantly the biggest circumferences.

Yield. The Redhaven cultivar produced significantly higher average yields (from 26.6 to 30.7 kg per tree) compared to Royal Glory (from 14.9 to 18.5 kg per tree) in the fourth growing season. The absence of interaction between the rootstock and the cultivar (Table 7) indicates that rootstocks had consistent effects on both cultivars. Rootstock had no significant effect on the average yields (Table 2, Table 7). This may be due to the young trees, since similar yields on different rootstocks have previously been reported in the years before full production.[31] There was a significant effect of the rootstock on cumulative yield in combination with the Tebana cultivar; however, the yield was not affected in combination with the Queen Giant cultivar.[11] Other authors,[8,10,32] on the other hand, have reported a significant rootstock-induced effect on the yield. Pronounced effect of the rootstock and cultivar on the crop load as well as on yield efficiency was evident (Table 7). Hrotko et al. also found significant effect of rootstocks on yield efficiency of plum trees,[6] while Larsen et al.[7] researched this using apple trees.

Quality Characteristics. Despite the difference in yields between the cultivars, both of them produced statistically similar average fruit weight, which indicates a greater production capacity of the Redhaven cultivar. A previous study showed a significantly higher fruit weight in the Redhaven cultivar in comparison with the Royal Glory,[33] which is in contradiction to our results. Fruit weight of peach is a function of crop load[32,34] as well as the time of thinning.[34] Since thinning was performed at a nearly identical development stage, only the statistically higher crop loads of Redhaven in comparison to Royal Glory in our study (Table 2) could have influenced a similar fruit weight of both cultivars and also could have influenced lower fruit weight of Redhaven than that reported by Tavarini et al.[33] Rootstocks affected the fruit weight of both cultivars. In combination with Redhaven, GF 677, Ishtara, and Penta produced significantly lighter fruit (156.6, 156.6, and 152.3 g, respectively), while Barrier 1 and Monegro, on average, produced heavier fruit. The lightest Royal Glory fruit were harvested from Barrier 1 and Ishtara grafted trees (147.7 and 148.1 g, respectively), while Penta produced the heaviest fruit on average (173.8 g). Significant interaction between rootstock and cultivar on fruit weight was evident and could have been affected by different crop load among rootstocks. A study of several peach rootstocks showed different susceptibility to alternating crop loads.[4] According to De Salvador[4] Barrier 1 and GF 677 rootstocks were more sensitive to an increased crop load, which resulted in smaller fruit. Ishtara, on the other hand, produced bigger fruit despite high crop loads. This is in accordance with our findings regarding the Royal Glory cultivar. In combination with the Redhaven cultivar, however, Barrier 1 rootstock, with a similar

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Table 3. Average Sugars Content (g/kg FW) ± Standard Error of Redhaven and Royal Glory on Different Rootstocks[a]

cultivar	rootstock	sucrose	glucose	fructose	sorbitol	total sugars
Redhaven	Adesoto	52.61 ± 0.58 b	5.50 ± 0.30 a	3.97 ± 0.25 b	1.07 ± 0.10 abc	62.90 ± 0.98 bc
	Barrier 1	52.98 ± 1.57 b	5.43 ± 0.10 a	3.33 ± 0.04 a	1.26 ± 0.12 bcd	63.58 ± 2.02 bc
	GF 677	52.88 ± 0.93 b	5.55 ± 0.18 a	3.99 ± 0.15 b	1.59 ± 0.09 d	63.85 ± 0.81 bc
	Ishtara	45.82 ± 2.08 a	5.24 ± 0.17 a	3.38 ± 0.09 a	0.94 ± 0.05 ab	55.39 ± 2.22 a
	Monegro	49.78 ± 2.53 ab	5.79 ± 0.19 a	3.37 ± 0.16 a	1.33 ± 0.24 cd	59.80 ± 3.10 ab
	Penta	54.06 ± 1.85 b	6.50 ± 0.26 b	4.61 ± 0.14 c	1.63 ± 0.07 d	66.43 ± 2.23 c
	Peach seedling	45.91 ± 2.01 a	5.55 ± 0.31 a	3.25 ± 0.23 a	0.77 ± 0.07 a	55.62 ± 2.00 a
Royal Glory	Adesoto	54.66 ± 0.59 c	8.55 ± 0.22 ab	5.85 ± 0.21 ab	2.44 ± 0.14	71.28 ± 0.52 ab
	Barrier 1	47.50 ± 1.84 ab	9.70 ± 0.44 cd	6.97 ± 0.42 cd	2.84 ± 0.32	69.12 ± 2.90 ab
	GF 677	55.60 ± 0.47 c	10.22 ± 0.31 d	7.52 ± 0.12 d	2.36 ± 0.19	75.50 ± 1.31 b
	Ishtara	51.47 ± 1.29 bc	7.70 ± 0.08 a	6.40 ± 0.38 bc	2.18 ± 0.06	67.11 ± 0.21 a
	Monegro	45.86 ± 2.42 a	9.08 ± 0.28 bc	6.29 ± 0.24 bc	2.20 ± 0.28	66.52 ± 3.81 a
	Penta	60.39 ± 1.07 d	7.77 ± 0.26 a	5.45 ± 0.28 ab	2.51 ± 0.32	76.13 ± 0.77 b
	Peach seedling	53.46 ± 2.18 c	7.91 ± 0.39 a	5.24 ± 0.24 a	2.39 ± 0.24	69.49 ± 2.52 ab

[a] Different letters in columns for each cultivar indicate significantly different values at $p < 0.05$.

Table 4. Average Organic Acids Content (g/kg FW for citric and malic acids and in mg/kg FW for shikimic and fumaric acids) ± Standard Error of Redhaven and Royal Glory on Different Rootstocks[a]

cultivar	rootstock	malic acid	citric acid	shikimic acid	fumaric acid	total acids
Redhaven	Adesoto	3.71 ± 0.09 a	1.32 ± 0.10 a	43.93 ± 0.09	7.09 ± 0.11 a	5.08 ± 0.14 a
	Barrier 1	5.07 ± 0.15 d	1.74 ± 0.06 b	48.66 ± 1.54	10.03 ± 1.34 b	6.55 ± 0.25 c
	GF 677	3.65 ± 0.12 a	1.35 ± 0.06 a	47.94 ± 1.36	6.71 ± 0.18 a	5.06 ± 0.13 a
	Ishtara	3.85 ± 0.11 ab	1.28 ± 0.04 a	44.60 ± 1.27	7.34 ± 0.16 a	5.18 ± 0.10 a
	Monegro	4.27 ± 0.07 c	1.35 ± 0.14 a	45.94 ± 1.60	7.00 ± 0.22 a	5.49 ± 0.10 ab
	Penta	4.12 ± 0.02 bc	1.58 ± 0.16 ab	46.15 ± 0.71	7.84 ± 0.18 a	5.69 ± 0.20 b
	Peach seedling	4.04 ± 0.12 bc	1.80 ± 0.11 b	46.24 ± 1.02	7.04 ± 0.26 a	5.79 ± 0.07 b
Royal Glory	Adesoto	2.68 ± 0.16	1.72 ± 0.04 abc	39.3 ± 0.90 bc	8.40 ± 0.51 c	4.57 ± 0.07
	Barrier 1	2.47 ± 0.20	2.38 ± 0.08 d	37.8 ± 0.61 bc	6.25 ± 0.63 ab	4.61 ± 0.24
	GF 677	2.63 ± 0.12	2.02 ± 0.06 c	41.3 ± 2.22 c	7.20 ± 0.58 abc	4.60 ± 0.17
	Ishtara	2.66 ± 0.09	1.87 ± 0.09 bc	38.0 ± 1.71 bc	6.00 ± 0.00 a	4.48 ± 0.12
	Monegro	2.67 ± 0.09	1.62 ± 0.15 ab	33.5 ± 0.58 a	7.40 ± 0.51 abc	4.33 ± 0.10
	Penta	3.16 ± 0.18	1.48 ± 0.11 a	36.2 ± 1.61 ab	8.40 ± 0.87 c	4.47 ± 0.20
	peach seedling	2.87 ± 0.06	1.47 ± 0.13 a	33.2 ± 1.13 a	8.00 ± 0.45 bc	4.43 ± 0.11

[a] Different letters in columns for each cultivar indicate significantly different values at $p < 0.05$.

crop load as GF 677, produced significantly heavier fruit, indicating that not all cultivar−rootstock combinations work well and that identification of good combinations over several seasons may be necessary.

No significant differences in soluble solids contents were found between the two cultivars (Table 7). Soluble solids content levels were also not affected by the rootstock in the Redhaven fruit, ranging from 8.9 °Bx (peach seedling) to 9.7 °Bx (Barrier 1). On the other hand, the rootstock had a significant effect on soluble solids content in the Royal Glory fruit, which is in accordance with the results of a recent research on a Suncrest cultivar, where two identical rootstocks (GF 677 and Penta) were studied.[13] The Penta rootstock gave the highest soluble solids content (10.04 °Bx). The interaction between the rootstock and the cultivar for soluble solids content was significant. Some authors have reported that soluble solids content was not affected by the rootstocks.[2,5] De Salvador[4] reported that an increase of crop load negatively affected soluble solids contents in the fruit from Barrier 1 grafted trees. Similar soluble solids contents in the Redhaven fruit and significantly different in the Royal Glory fruit at different crop loads imply that each cultivar may interact specifically with the same rootstock.

Sugar and Organic Acid Content. It has been established, that levels of individual sugar contents in peach fruit differ among cultivars,[20] which is consistent with our results (Table 7). Rootstocks influenced the levels of sucrose, glucose, fructose and total sugars in fruit from both cultivars (Table 3), and their content levels are similar to early studies.[8,20,35] The Penta rootstock had a significant influence on high sucrose, glucose, fructose, sorbitol, and total sugar levels in the Redhaven cultivar. Ishtara, on the other hand, influenced the lowest contents of sucrose, glucose, and total sugars contents in the Redhaven fruit. The results are different to those reported in 2008.[8] The differences may have occurred because of different climatic conditions as well as different yields of the trees. In combination with the Royal Glory cultivar, the GF 677 rootstock produced fruit with high levels of glucose, fructose, and total sugars. In combination with Royal Glory, Ishtara produced fruit with low levels of glucose, sorbitol,

Table 5. Phenolics Content in Skin and Pulp (mg/kg FW) in Redhaven and Royal Glory Peach Fruit on Different Rootstocks[a]

		pulp			skin	
cultivar	rootstock	neochlorogenic acid	chlorogenic acid	*p*-coumaric acid	neochlorogenic acid	chlorogenic acid
Redhaven	Adesoto	11.16 ± 1.69 b	7.73 ± 0.86 bc	0.19 ± 0.030 bcd	17.38 ± 2.24 bc	68.12 ± 5.39 b
	Barrier 1	9.81 ± 0.87 b	10.64 ± 0.69 cd	0.20 ± 0.014 cd	14.83 ± 0.49 ab	152.27 ± 9.66 c
	GF677	3.26 ± 0.43 a	2.83 ± 0.34 a	0.15 ± 0.025 abc	15.60 ± 1.29 abc	43.81 ± 6.29 a
	Ishtara	10.05 ± 0.93 b	9.08 ± 1.01 bcd	0.12 ± 0.013 ab	21.08 ± 2.97 cd	56.90 ± 2.55 ab
	Monegro	6.02 ± 0.44 a	6.19 ± 1.15 b	0.11 ± 0.010 a	10.37 ± 1.19 a	50.63 ± 4.37 ab
	Penta	10.44 ± 1.05 b	10.45 ± 0.91 cd	0.23 ± 0.033 de	10.18 ± 1.48 a	50.38 ± 8.14 ab
	Peach seedling	11.29 ± 1.23 b	11.34 ± 1.24 d	0.28 ± 0.030 e	26.16 ± 3.15 d	50.29 ± 8.91 ab
Royal Glory	Adesoto	5.85 ± 0.23 ab	9.44 ± 0.45 ab	0.11 ± 0.0050 b	10.09 ± 1.52	28.14 ± 4.40 a
	Barrier 1	6.54 ± 1.23 ab	7.62 ± 1.79 ab	0.10 ± 0.0061 b	12.72 ± 1.38	57.39 + 1.40 c
	GF677	7.37 ± 0.41 b	11.61 ± 1.02 bc	0.11 ± 0.0051 b	14.34 ± 1.96	77.96 + 5.67 d
	Ishtara	4.43 ± 0.42 a	5.98 ± 0.42 a	0.09 ± 0.0089 ab	11.35 ± 0.72	23.87 ± 3.24 a
	Monegro	4.49 ± 0.42 a	14.21 ± 1.86 c	0.07 ± 0.0075 a	11.53 ± 1.02	37.91 ± 3.53 ab
	Penta	4.52 ± 0.18 a	8.24 ± 0.71 ab	0.11 ± 0.0138 b	10.01 ± 0.92	29.20 ± 4.74 a
	Peach seedling	6.72 ± 0.50 b	9.41 ± 1.03 ab	0.09 ± 0.0035 ab	14.17 ± 1.83	48.63 ± 6.78 bc

[a] Different letters in columns for each cultivar indicate significantly different values at $p < 0.05$.

Table 6. Flavonol and Anthocyanin Content Levels (mg/kg FW) in Skin of Redhaven and Royal Glory Peach Fruit on Different Rootstocks[a]

cultivar	rootstock	Q 3-gal[x]	Q 3-rut[r]	Q 3-glu[y]	Q 3-rham[z]	Cy 3-glu[s]	Cy 3-rut[k]
Redhaven	Adesoto	12.12 ± 1.54	26.08 ± 2.49	34.87 ± 2.00	7.23 ± 0.95	497.10 ± 37.18 ab	16.02 ± 1.96 a
	Barrier 1	11.00 ± 2.08	22.66 ± 4.96	25.12 ± 4.89	5.73 ± 1.29	687.88 ± 104.26 b	35.05 ± 4.99 c
	GF677	8.98 ± 1.13	18.09 ± 4.71	17.01 ± 4.29	5.58 ± 1.05	404.43 ± 94.44 a	16.71 ± 4.85 a
	Ishtara	9.60 ± 2.03	16.74 ± 3.77	28.66 ± 4.36	4.80 ± 1.12	625.35 ± 55.47 ab	22.95 ± 2.28 ab
	Monegro	9.51 ± 1.10	17.80 ± 1.71	27.23 ± 3.31	3.85 ± 0.24	693.89 ± 44.88 b	31.26 ± 4.16 bc
	Penta	9.14 ± 1.94	18.90 ± 4.04	24.75 ± 5.36	4.30 ± 1.00	535.82 ± 79.99 ab	23.70 ± 4.81 ab
	Peach seedling	8.15 ± 0.58	16.24 ± 2.69	20.72 ± 2.63	4.53 ± 0.74	437.15 ± 20.01 a	16.91 ± 0.86 a
Royal Glory	Adesoto	8.51 ± 0.69	21.84 ± 2.15	29.94 ± 4.05 bc	3.29 ± 0.41	580.00 ± 92.92	3.32 ± 0.33
	Barrier 1	7.84 ± 0.48	21.90 ± 0.89	27.86 ± 0.91 ab	3.13 ± 0.17	451.16 ± 32.14	3.45 ± 0.55
	GF677	6.02 ± 0.91	14.58 ± 2.97	17.48 ± 3.44 a	2.99 ± 0.58	460.28 ± 74.35	3.01 ± 0.70
	Ishtara	7.75 ± 0.99	21.09 ± 3.45	24.90 ± 3.15 ab	2.98 ± 0.45	388.03 ± 37.77	1.69 ± 0.19
	Monegro	9.55 ± 0.67	24.31 ± 1.28	37.88 ± 0.50 c	3.71 ± 0.23	515.94 ± 44.75	2.70 ± 0.45
	Penta	7.50 ± 1.02	18.39 ± 1.24	19.25 ± 5.00 a	3.07 ± 0.37	486.04 ± 33.68	2.63 ± 0.50
	Peach seedling	7.43 ± 0.67	18.57 ± 1.44	22.05 ± 1.71 ab	3.14 ± 0.29	344.97 ± 92.81	2.07 ± 0.32

[a] Different letters in columns for each cultivar indicate significantly different values at $p < 0.05$. Legend for superscript letters: x, quercetin 3-*O*-galactoside; y, quercetin 3-glucoside; z, quercetin 3-rhamnoside; r, quercetin 3-*O*-rutinoside; s, cyanidin 3-*O*-glucoside; k, cyanidin 3-*O*-rutinoside.

and total sugars. We can assume that low levels of sucrose, glucose, fructose, and total sugars in Redhaven and glucose and sorbitol in the Royal Glory fruit from the Ishtara rootstock could be affected by a high crop load. Usenik et al.[36] previously reported that higher crop loads (low leaf-to-fruit ratio) caused lower contents of glucose, fructose, and sorbitol levels in cherry fruit. High levels of all individual and total sugars in the Redhaven fruit from the Penta rootstock, however, contradict this assumption, since relatively high crop loads in comparison to other rootstocks were found. The Monegro rootstock in combination with both cultivars produced fruit with low levels of several individual sugars despite a low crop load. It is evident from our results that the content of primary metabolites may be a function of at least three factors, cultivar, rootstock, and crop load, and their interactions.

According to Colaric et al.[20] cultivar affects organic acids levels, which is in accordance with our results (Table 7). We discovered a significant effect of rootstock on citric, malic, fumaric, and total acids in the Redhaven fruit and on citric, shikimic, and fumaric acids in the Royal Glory fruit (Table 4). The values measured are similar to those reported previously.[8,20,35] High levels of malic, citric, fumaric, and total acid were found in the Redhaven fruit on Barrier 1 rootstock. Low levels of all acids were measured in the Redhaven fruit on Adesoto, GF 677, and the Ishtara rootstock. None of the studied rootstocks influenced high levels of organic acids in general in the Royal Glory, while in the fruit from peach seedling low levels of citric and shikimic acid were measured. Usenik et al.[36] reported that higher crop load affected high levels of malic acid and total acids in the sweet cherry fruit. This is in contradiction with our results for the Redhaven fruit on the Ishtara rootstock, where low levels of organic acids were measured despite high crop load. It can even be assumed that crop load marginally influences the organic acid levels, since at similar crop loads of the

Table 7. Significance for the Effect for Rootstock and Cultivar and Their Interaction on Yield, Circumference, Crop Load, Yield Efficiency, Fruit Physical, and Chemical Characteristics of Peach[a]

parameter[b]	rootstock	cultivar	rootstock × cultivar
yield	NS	***	NS
circumference	***	***	NS
crop load	***	***	***
yield efficiency	***	***	*
weight	NS	NS	**
soluble solids	NS	NS	***
sucrose	***	*	**
glucose	***	***	***
fructose	***	***	***
sorbitol	*	***	NS
total sugars	***	***	NS
citric acid	***	***	***
malic acid	***	***	***
shikimic acid	**	***	*
fumaric acid	NS	NS	***
total acids	***	***	***
neochlorogenic acid, pulp	***	***	***
chlorogenic acid, pulp	*	*	***
p-coumaric acid, pulp	***	***	***
neochlorogenic acid, skin	***	***	***
chlorogenic acid, skin	***	***	***
Q 3-gal[x], skin	NS	**	NS
Q 3-rut[r], skin	NS	NS	NS
Q 3-glu[y], skin	***	NS	NS
Q 3-rham[z], skin	NS	***	NS
Cy 3-glu[s], skin	*	**	NS
Cy 3-rut[k], skin	**	***	**

[a] NS, not significant; *, significant differences at *P*-value below 0.05; **, significant differences at *P*-value below 0.01; ***, significant differences at *P*-value below 0.001. [b] Legend for superscript letters: x, quercetin 3-*O*-galactoside; y, quercetin 3-glucoside; z, quercetin 3-rhamnoside; r, quercetin 3-*O*-rutinoside; s, cyanidin 3-*O*-glucoside; k, cyanidin 3-*O*-rutinoside.

Redhaven on Adesoto, Barrier 1, and GF 677 contrasting levels of organic acids were found.

Phenolics. In Table 5, we present phenolic compounds (neochlorogenic acid, chlorogenic acid, and *p*-coumaric acid) in pulp and skin, and in Table 6 we present flavonols (quercetin 3-galactoside, quercetin 3-rutinoside, quercetin 3-glucoside, and quercetin 3-rhamnoside) and anthocyanins (cyanidin 3-glucoside and cyanidin 3-rutinoside) in the skin of Redhaven and Royal Glory fruit.

In the peach fruit skin, chlorogenic acid was present in highest concentrations among the identified phenolics, followed by neochlorogenic acid. Content levels obtained are similar to those from the previous study;[8] however, they are lower compared to those reported by Tomás-Barberán et al.[21] Differences may have occurred because of different extraction and analysis methods.

Significant effect of the rootstock on phenolics compounds in the pulp was evident for both cultivars, which is in accordance with the previous study of total phenolics and individual phenolic contents.[8] High concentrations of neochlorogenic, chlorogenic, and *p*-coumaric acid were found in the pulp of the Redhaven fruit harvested from the Penta and peach seedling rootstocks. The low contents of phenolics were found in the pulp of the Redhaven fruit harvested from the GF 677 and Monegro rootstocks. High concentrations of neochlorogenic, chlorogenic, and *p*-coumaric acid were found in the pulp of the Royal Glory fruit on the GF 677 rootstock. The low content of phenolics was found in the pulp of the Royal Glory fruit from the Ishtara rootstock. Phenolic acids are, among other factors, maturity-dependent.[25] Since fruit from each cultivar were of similar ripeness, these differences can only be attributed to the influence of the rootstock, which is in accordance with the previous studies on peach[8] and sweet cherry.[37] The rootstock effects on levels of phenolics in pulp of the Royal Glory differed from those of the Redhaven, indicating that the interaction between the rootstock and the cultivar also influences the levels of phenolics in the pulp of peach fruit. According to Tomas-Barberan et al.[21] some cultivars contain very high levels of phenolics compounds that could be heightened or lowered with the selection of a certain rootstock. This would have a crucial impact on the health-promoting properties of peach fruit.[21]

Rootstock had a significant influence on various levels of neochlorogenic and chlorogenic acids in the skin of the Redhaven fruit. High levels of neochlorogenic acid were again measured in the peach seedling fruit as well as in the Ishtara fruit. The Monegro and Penta rootstock yielded low levels of neochlorogenic acid in the skin. By far the highest concentrations of chlorogenic acid were found in the skin of fruit from the Barrier 1 grafted trees. These were followed by fruit harvested from the Adesoto grafted trees. The GF 677 rootstock gave the lowest levels of chlorogenic acid in the skin of the Redhaven fruit. Neochlorogenic acid levels were unaffected by rootstocks in the Royal Glory fruit, while significant differences were found in the chlorogenic acid levels. As with the pulp tissue, GF 677 gave the highest levels of chlorogenic acid in the skin of the Royal Glory fruit. Barrier 1 and peach seedling also produced the Royal Glory fruit with elevated levels of chlorogenic acid in the skin.

Among flavonols, quercetin 3-glucoside was present in the highest concentrations, closely followed by quercetin 3-rutinoside, quercetin 3-galactoside, and quercetin 3-rhamnoside. Similar content levels have been reported previously,[21] while somewhat lower values of flavonols in the Redhaven fruit were found in a previous study,[8] which indicates seasonal fluctuations of these metabolites. Except for quercetin 3-glucoside levels in the skin of the Royal Glory, similar levels of quercetin 3-rutinoside and quercetin 3-glucsoide were measured in the skin from both cultivars, indicating that flavonols in the skin are not affected by the rootstock or cultivar in comparison to phenolic acids. According to Awad et al.[38] the regulation of crop load does not affect flavonoids in the skin of an apple, which is in accordance with our results.

Content levels of cyanidin 3-glucoside were twice as high compared to those recorded in the literature, while those of cyanidin 3-rutinoside were similar to previous publications.[8,21] Barrier 1 and Monegro produced fruit with statistically the highest levels of both anthocyanins in the skin of the Redhaven fruit. On the other hand, GF 677 and peach seedling induced low levels of anthocyanins. Anthocyanins in the skin of the Royal Glory peach fruit were unaffected by rootstocks. Anthocyanins are present in higher concentrations in fruit with intensive red coloration.[39] Similar levels of anthocyanins were measured in the skin of the Royal Glory and in the Redhaven cultivar. Royal Glory is the cultivar that in the early stage of maturity gains an intense red coloration covering most of the fruit.[40]

We can conclude that selecting the right combination of the rootstock and cultivar is important for the chemical characteristics of peach fruit. In combination with the Redhaven in general, the Barrier 1 rootstock produced the best fruit (high yields of good average fruit weight). The Penta rootstock also produced good quality fruit in combination with the Redhaven; however, it should be thinned more intensively to improve fruit weight. In combination with the Royal Glory again the Penta rootstock in general produced good quality (high levels of several primary and secondary metabolites) as well as reached similar yields in comparison to other rootstocks. In addition, the Penta rootstock produced the smallest trees, hence easier to cultivate. Unfortunately, none of the rootstocks improved all of the quality parameters.

We have established that the extent to which rootstocks affect certain parameters varies from cultivar to cultivar. We found similar effects of the rootstock on vigor. Fruit weight, sugars, organic acids, and phenolic acid content levels were significantly affected by the rootstock. Flavonols, with the exception of quercetin 3-glucoside, on the other hand, were unaffected by any of the rootstocks.

It is undisputed that the effect of the rootstock on fruit trees is considerably more complex than can be measured by vigor alone. Field performance of the rootstock is still the main criterion for its selection; however, its effect on fruit quality should not be overlooked. Nowadays, good quality fruit is more and more associated with the health-promoting benefits of the fruit and should, therefore, also be included in the studies to provide growers with information about which cultivars and rootstocks will provide the best results.

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2.3 PRIMERJAVA DESETIH BRESKOVIH PODLAG, CEPLJENIH S SORTO 'REDHAVEN'

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Comparison of ten peach rootstocks performance grafted with 'Redhaven' cultivar

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Slovenski sadjarji so za napravo prve generacije breskovega sadovnjaka uporabljali sejanec breskve in za njim podlago 'GF 677', ki je križanec breskve in mandlja. Ena od nalog stroke je tudi posredovanje informacij o primernih kombinacijah posameznih sort in podlag v naših talnih in podnebnih razmerah, ki so pridelovalcem v veliko pomoč pri napravi novega nasada. Naš namen je bil ovrednotiti vpliv različnih podlag na posamezne parametre zunanje in notranje kakovosti plodov.

V Sadjarskem centru Bilje smo leta 2008 in 2009 spremljali nekatere parametre kakovosti plodov breskve sorte 'Redhaven', ki je bila leta 2005 cepljena na enajst različnih podlag ('Adesoto', 'Barrier 1', 'Cadaman', 'GF 677', 'Julior', 'Ishtara', 'MrS 2/5', 'Monegro', 'Penta', sejanec in 'Tetra'). Razlike v meritvah trdote in osnovne barve so pokazale, da so posamezne podlage ('Monegro' leta 2008 in 'Cadaman' leta 2009) vplivale na poznejše dozorevanje plodov. Pri drugih podlagah odstopanj v hitrosti dozorevanja nismo opazili. Pri podlagah smo, najverjetneje zaradi razlik v pridelku na drevo, ugotovili razlike v masi plodov. Tudi pri analizah vsebnosti skupnih sladkorjev in organskih kislin ter njihovem razmerju smo ugotovili razlike med podlagami. Dvoletni rezultati so pokazali, da sta imeli podlagi 'Adesoto' in 'Tetra' pozitiven vpliv na kakovost plodov, ki se je odrazil v visokih vrednostih določenih parametrov (vsebnosti suhe snovi, skupnih sladkorjev in organskih kislin ter njihovem ugodnem razmerju.

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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 appealing 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-

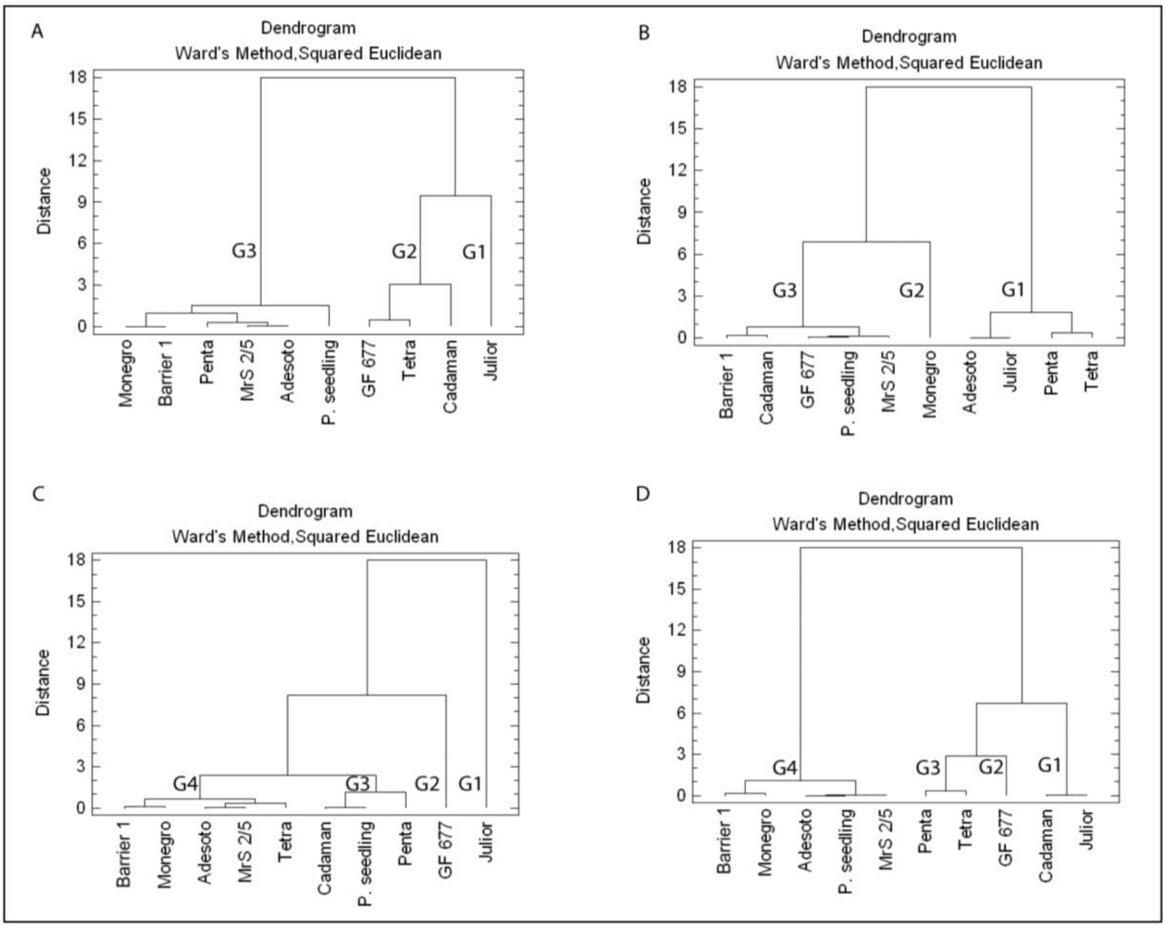

Fig. 1. Dendrograms of ten peach rootstocks in virgin (A) and replant soil (B) in 2008 and in virgin (C) and replant soil (D) in 2009 using the ward method based on the square Euclidean distance from fruit firmness and ground colour. G 1 to G 4 represents different groups of fruit maturity.

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.

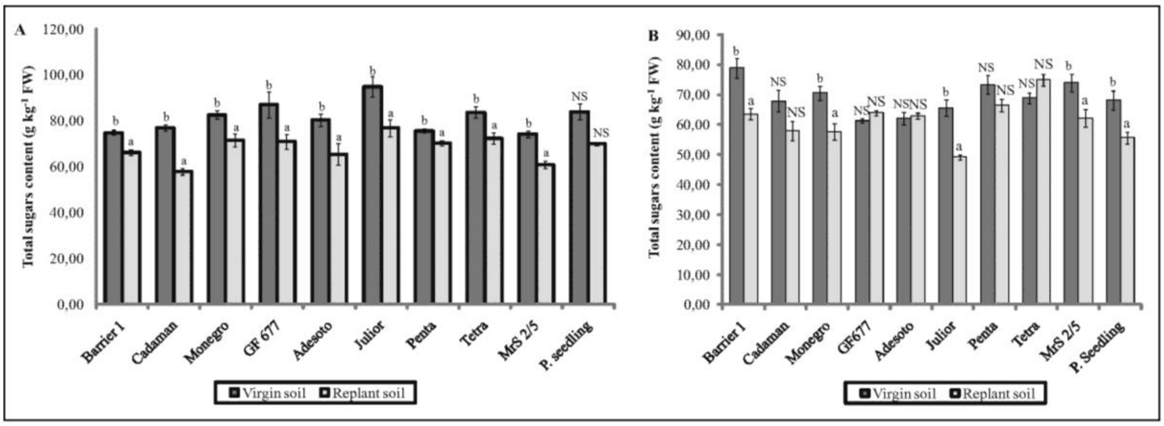

Fig. 2. Total sugar content in 2008 (A) and 2009 (B) and in 'Redhaven' peach fruit grafted on ten rootstocks. Different letters denote statistically significant differences between the two soil types for individual rootstocks using one-way analysis of variance (LSD test with P-value < 0.05)

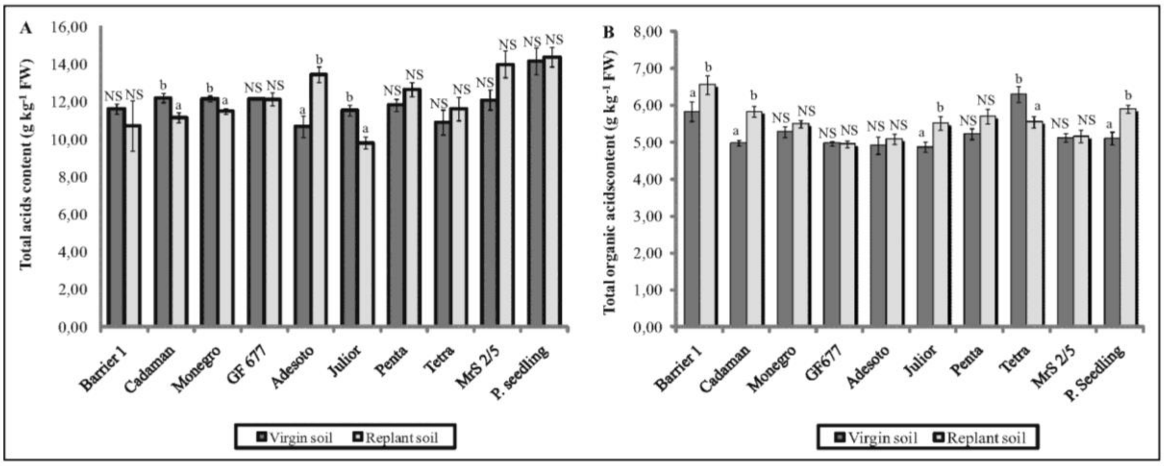

Fig. 3. Total organic acids content in 2008 (A) and 2009 (B) and in 'Redhaven' peach fruit grafted on ten rootstocks. Different letters denote statistically significant differences between the two soil types for individual rootstocks using one-way analysis of variance (LSD test with P-value < 0.05)

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,

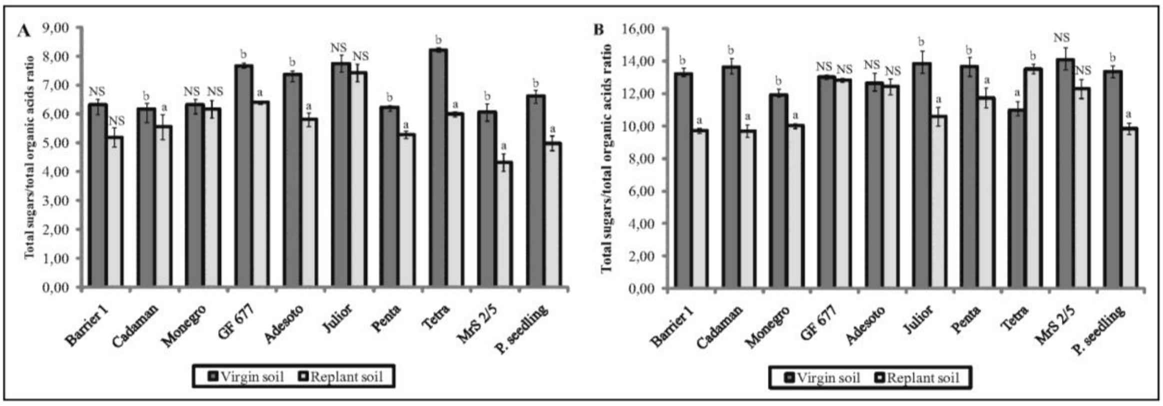

Fig. 4. Sugars/organic acids ratio in 2008 (A), sugars/organic acids ratio in 2009 (B) and in ‘Redhaven’ peach fruit grafted on ten rootstocks. Different letters denote statistically significant differences between the two soil types for individual rootstocks using one-way analysis of variance (LSD test 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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3 RAZPRAVA IN SKLEPI

3.1 RAZPRAVA

V Sadjarskem centru Bilje pri Novi Gorici smo v dveh zaporednih letih, 2008 in 2009, spremljali pomološke lastnosti in vsebnosti primarnih in sekundarnih metabolitov v plodovih breskve sorte 'Redhaven', leta 2009 pa tudi sorte 'Royal Glory', cepljene na enajst različnih podlag. Poleg kakovostnih parametrov smo vsako leto zabeležili tudi prirast debla ter skupni pridelek. Vsaka kombinacija sorte in podlage je bila zasajena na deviških in utrujenih tleh. Dvanajst dreves posamezne kombinacije sorte, podlage in tal je predstavljalo eno obravnavanje.

Pri sorti 'Redhaven' smo leta 2008 pri vseh kombinacijah zabeležili vrh cvetenja 24. marca. Prvo obiranje pri vseh obravnavanjih smo opravili 23. julija. Z vidika zorenja je bilo leto 2008 znotraj povprečja, ki ga navajajo Godec in sod. (2011). Leta 2009 smo vrh cvetenja zabeležili 23. marca, prvo obiranje pa smo opravili zelo zgodaj, in sicer 16. julija. Sorta 'Royal Glory' je leta 2009 cvetela 27. marca, prvo obiranje pa smo opravili 6. julija. Godec in sod. (2011) navajajo, da naj bi sorta 'Royal Glory' v povprečju zorela pet dni pred sorto 'Redhaven'. Tako primerjava naših podatkov in podatkov, ki jih navajajo Godec in sod. (2011) kaže na to, da je bilo zorenje sorte 'Royal Glory' v letu 2009 glede na čas zorenja sorte 'Redhaven' nekoliko zgodnejše.

Pri sorti 'Redhaven' so se do leta 2009 obdržala vsa drevesa na podlagi 'Ishtara' na utrujenih in deviških tleh (priloga A). Vsa drevesa so se obdržala na deviških tleh tudi pri podlagah 'GF 677' in 'Monegro'. Pri podlagah 'Barrier 1' in 'Tetra' je na deviških tleh propadlo po eno drevo, po tri drevesa pa so propadla pri podlagah sejanec, 'Cadaman', 'Adesoto', 'MrS 2/5', in 'Penta'. Največ propadlih dreves smo na deviških tleh zabeležili pri podlagi 'Julior', kjer jih je propadlo osem. Na utrujenih tleh je pri sorti 'Redhaven' skupno propadlo manj dreves kot na deviških tleh. Na utrujenih tleh so se pri podlagah 'Ishtara' in 'Penta' obdržala vsa drevesa, po eno drevo je propadlo pri podlagah sejanec, 'Adesoto' in 'Tetra', po dve pri podlagah 'Monegro', 'Cadaman' in 'Julior' ter po tri pri podlagah 'GF 677' in 'Barrier 1'. V kombinaciji s sorto 'Royal Glory' na deviških tleh pri podlagi 'Monegro' ni propadlo nobeno drevo, le po eno pa pri podlagah 'Adesoto', 'Ishtara', 'Penta' in 'Tetra'. Pri podlagi 'Julior' sta na deviških tleh propadli dve drevesi, pri podlagah sejanec in 'Barrier 1' pa tri drevesa. Podlage 'GF 677', 'Cadaman' in 'MrS 2/5' so se na deviških tleh izkazale kot slabe, saj so pri podlagah 'Cadaman' in 'MrS 2/5' propadla štiri, pri podlagi 'GF 677' pa kar šest dreves. Na utrujenih tleh je pri sorti 'Royal Glory' propadlo manj dreves kot na deviških tleh. Vsa drevesa so se na utrujenih tleh obdržala pri podlagah 'GF 677', 'MrS 2/5', 'Ishtara', 'Penta' in 'Tetra', po eno pa je propadlo pri podlagah 'Barrier 1', 'Cadaman' in 'Adesoto'. Pri podlagah sejanec in 'Monegro' sta propadli po dve drevesi, pri podlagi 'Julior' pa tri drevesa na utrujenih tleh. Rezultati kažejo, da se na utrujenih tleh ni izrazil problem ponovnega sajenja, saj je pri obeh sortah na utrujenih tleh propadlo manj dreves kot na deviških. V nasprotju s pričakovanji je pri večini podlag na deviških tleh propadlo več dreves kot na utrujenih.

Razlog za to bi lahko bile različne bolezni in škodljivci, katerih natančna analiza bi mogoče dala odgovor, zakaj so drevesa propadla. Kljub nepričakovanim rezultatom, lahko priporočimo podlage 'Ishtara' in 'Tetra' tako za deviška kot utrujena tla, podlago 'Monegro' za deviška, podlagi 'Adesoto' in 'Penta' pa za utrujena tla.

3.1.1 Vpliv podlage, tal in sorte na bujnost in pridelek

Bujnost drevesa je ena od najpomembnejših lastnosti, na katero vplivajo podlage in jo s pravilno izbiro pri večini sadnih vrst lahko uravnavamo. Drevesa, ki smo jih spremljali v našem poskusu, so glede bujnosti in pridelka po posameznih letih v okviru diplomskih raziskav opisali različni avtorji (Andrejčič, 2010; Komel, 2010; Škvarč, 2010; Zemljič, 2010; Heric, 2011; Repovž, 2011; Alič, 2012). Trenutno se za standardno podlago v intenzivnih breskovih sadovnjakih uporablja 'GF 677', ki je v zadnjih desetletjih nadomestila sejanec breskve. Po bujnosti 'GF 677' uvrščamo med bujne podlage. V naši raziskavi smo bujnost dreves ovrednotili s pomočjo obsega debla izmerjenega približno 20 cm nad cepljenim mestom drevesa. Kasneje smo obsege dreves različnih podlag primerjali z obsegom dreves posajenih na standardni podlagi 'GF 677'.

Leta 2009 smo na utrujenih tleh primerjali vpliv izbranih podlag na bujnost pri sortah 'Redhaven' in 'Royal Glory' (Orazem in sod., 2011c). Statistično neznačilna interakcija med sortama in podlagami dokazuje enoten vpliv podlag na bujnost dreves pri obeh sortah. Pri sorti 'Royal Glory' smo izmerili statistično značilno večje obsege debel, kar potrjuje ugotovitve avtorjev Öhlinger in sod. (2008).

Merilo za razvrstitev podlag po bujnosti: bujne podlage (od 10 % večji obseg debla do 10 % manjši obseg debla kot pri podlagi 'GF 677'), srednje bujne podlage (od 11 % do 20 % manjši obseg debla kot pri 'GF 677') ter šibke podlage (več kot 21 % manjši obseg debla kot pri 'GF 677'). Pregled objavljenih diplomskih del pokaže razlike v bujnosti dreves pri posamezni sorti, prav tako pa so na bujnost vplivala tudi tla.

Najbujnejšo rast dreves sorte 'Redhaven' na deviških tleh smo izmerili pri podlagah 'GF 677', 'Barrier 1' in 'Monegro', srednje bujna je bila rast pri podlagah 'Julior', 'Cadaman', 'Adesoto', sejanec in 'Tetra', šibka pa pri podlagah 'MrS 2/5', 'Penta' in 'Ishtara' (Škvarč, 2010). Tudi na utrujenih tleh so na bujno rast dreves sorte 'Redhaven' vplivale enake podlage kot na deviških tleh, poleg njih pa še podlage 'MrS 2/5', 'Cadaman' in 'Adesoto'. Podlage 'Julior', sejanec in 'Tetra' so, podobno kot na deviških tleh, vplivale na srednje bujno rast, poleg njih pa tudi podlaga 'Penta'. Podlaga 'Ishtara' je enako kot na deviških tudi na utrujenih tleh vplivala na najšibkejšo rast dreves sorte 'Redhaven' (Heric, 2011).

Pri sorti 'Royal Glory' smo zaznali manjše razlike v bujnosti dreves med tlemi. Bujno rast dreves smo na obeh tleh izmerili pri podlagah 'Monegro', 'Cadaman', 'GF 677', 'Barrier 1', sejanec in 'Adesoto' (Komel, 2010; Alič, 2012). Na deviških tleh so na srednje bujno rast vplivale podlage 'Penta', 'Julior' in 'Ishtara', na šibko pa podlagi 'MrS 2/5' in

'Tetra' (Komel, 2010). Na utrujenih tleh sta slivovi podlagi 'Tetra' in 'Penta' vplivali na srednje bujno, podlage 'Julior', 'MrS 2/5' in 'Ishtara' pa na šibko rast dreves (Alič, 2012).

Zanimiva je ugotovitev, da so bili pri sorti 'Redhaven' obsegi debel pri vseh podlagah večji na utrujenih (Heric, 2011) kot na deviških tleh (Škvarč, 2010), kar je v nasprotju s pričakovanji. Pri sorti 'Royal Glory' so bile pri posamezni podlagi razlike med deviškimi in utrujenimi tlemi manjše (Komel, 2010; Alič, 2012) in v primeru podlage 'Ishtara' v prid deviškim tlom, kar bi lahko nakazovalo slabšo primernost za utrujena tla. Rezultati kažejo, da bujnost rasti na utrujenih tleh ni bila manjša. Zucconi (1993) navaja, da utrujena tla vplivajo na zmanjšanje bujnosti rasti.

Pridelek na drevo je bil pri obeh sortah na obeh tleh leta 2009 večji v primerjavi z letom 2008 (Andrejčič, 2010; Komel, 2010; Škvarč, 2010; Zemljič, 2010; Heric, 2011; Repovž, 2011; Alič, 2012). Ti rezultati so pričakovani, saj sta bili to prvi dve leti rodnosti. V obdobju rasti drevesa do njegove polne rodnosti je povečevanje pridelka v normalnih klimatskih razmerah običajen pojav. Ker je bilo leto 2008 za obe sorti prvo rodno leto, je, še posebno pri sorti 'Royal Glory, prišlo do velikih odstopanj v pridelku na drevo. Znotraj posamezne sorte pa smo razlike zabeležili tako pri primerjavi posameznih podlag kakor tudi tipa tal. Prvo rodno leto je z vidika pridelka zelo pomembno, saj je že bilo dokazano, da nestalna količina pridelka ob vstopu drevesa v obdobje rodnosti, lahko pomembno vpliva na njegovo dozorevanje in kakovost.

Leta 2009 na utrujenih tleh nismo ugotovili statistično značilne interakcije med sorto in podlago v pridelku na drevo. Pri sorti 'Redhaven' se je bil pridelek med 26,7 kg/drevo in 30,7 kg/drevo in je bil statistično večji v primerjavi s sorto 'Royal Glory', kjer je znašal med 14,9 kg/drevo in 18,5 kg/drevo (Orazem in sod., 2011c). Pri sorti 'Redhaven' je bil leta 2009 na utujenih tleh pri vseh podlagah pridelek večji kot na deviških tleh (Škvarč, 2010; Heric, 2011). V tem letu smo pri sorti 'Royal Glory' pri vseh podlagah z izjemo 'Ishtare' in sejanca izmerili večji povprečni pridelek na drevo na deviških tleh (Komel, 2010; Alič, 2012). Leta 2009 smo pri vseh obravnavanjih pri sortah 'Redhaven' in 'Royal Glory' izmerili podoben povprečni pridelek (Orazem in sod., 2011c).

3.1.2 Vpliv podlage, tal in sorte na zorenje

Ker smo vsa obravnavanja obrali hkrati in ker je v preteklosti že bilo dokazano, da podlage lahko vplivajo na dolžino razvoja plodov (Autio, 1991; Beckman in sod., 1992; Iglesias in sod., 2004), smo na osnovi kazalnikov zrelosti opazovali vpliv podlag na zorenje plodov. Pri sorti 'Redhaven' smo v obeh letih na osnovi a^*-parametra osnovne barve in trdote plodov podlage razvrstili po zrelosti plodov (Orazem in sod., 2011a). Ugotavljali smo še, ali je ta vpliv enak na deviških in na utrujenih tleh. Na deviških tleh so bile podlage glede na zrelost plodov razvrščene v podobne skupine. Podlaga 'Julior' je v obeh letih vplivala na počasnejše dozorevanje plodov. Podlage 'Barrier 1', 'Monegro', 'MrS 2/5' in 'Adesoto' so vplivale na hitrejše dozorevanje plodov v obeh letih. Pri drugih podlagah se je na deviških tleh vpliv na dozorevanje plodov med leti razlikoval. Na utrujenih tleh smo med leti ugotovili večje razlike v vplivu na dozorevanje plodov. Podlage ‘Barrier 1’, ‘MrS 2/5’ in sejanec so v obeh letih vplivale na hitrejše dozorevanje, medtem ko se vpliv pri ostalih podlagah med leti ni ponovil. Razlike v stopnji zrelosti plodov bi lahko iskali v različni obremenjenosti dreves, ki lahko vpliva na hitrost dozorevanja plodov, o čemer pri češnji poročajo Usenik in sod. (2010a).

3.1.3 Vpliv podlage, tal in sorte na pomološke lastnosti

Ko govorimo o kakovosti plodov, podobno kot pri drugih sadnih vrstah, tudi pri breskvi najprej pomislimo na maso in z njo povezano velikost. Od velikosti plodov je odvisna tudi cena, saj imajo kupci rajši večje in posledično težje plodove (Marini, 2003). Velikost plodov uravnavamo z rezjo ter intenzivnostjo in terminom redčenja. Manjše število plodov vpliva na večjo velikost plodov in posledično večjo vrednost pridelka (Marini in Sowers, 1994). V našem poskusu so bila vsa drevesa enakomerno redčena glede na bujnost drevesa. Razlike v povprečni masi plodov so tako posledica vpliva podlag in njihove morebitne interakcije s tlemi in sorto.

Masa plodov je bila leta 2008 kljub manjšemu pridelku manjša kot leta 2009 (Orazem in sod., 2011a). Z izjemo podlage ‘GF 677’ v letu 2008, smo pri vseh podlagah izmerili podobno povprečno maso plodov na različnih tleh v obeh letih, kar kaže na majhen vpliv tal na to lastnost (Orazem in sod., 2011a). Leta 2009 med sortama nismo zaznali statistično značilnih razlik v povprečni masi plodov, kar bi lahko kazalo na večjo rodnost sorte ‘Redhaven’, saj smo pri njej hkrati izmerili večje pridelke na drevo (Orazem in sod., 2011c). V nasprotju z našimi rezultati Tavarini in sod. (2008) poročajo o večji povprečni masi plodov sorte ‘Redhaven’ in tudi o večji masi v primerjavi s sorto ‘Royal Glory’. V omenjeni razikavi so proučevali starejša drevesa, cepljena na drugo podlago (GF 557), kar bi lahko vplivalo na njihove zaključke.

V vseh opazovanih letih so podlage vplivale na razlike v povprečni masi plodov (Orazem in sod., 2011a, 2011b, 2011c). Značilna interakcija med sorto in podlago kaže, da podlage niso enotno vplivale na maso plodov obeh sort (Orazem in sod., 2011c). Do interakcije lahko pride, ker na maso plodov vplivajo številni dejavniki, med katerimi so najpomembnejši toletni in lanskoletni pridelek, preskrbljenost drevesa s hranili in vodo, homogenost oziroma nehomogenost tal kakor tudi vegetativni in generativni razvoj drevesa. Vse naštete dejavnike pa je bilo v okviru našega poskusa nemogoče izenačiti.

Vsebnost suhe snovi je eden od osnovnih kazalnikov kakovosti plodov. Čeprav je znano, da vsebnost suhe snovi z zorenjem narašča, je ta parameter med leti zelo spremenljiv in kot tak nezanesljiv kazalnik zrelosti (Crisosto, 1994). To so pokazali tudi naši rezulati, saj se je vsebnost suhe snovi pri sorti ‘Redhaven’ med letoma razlikovala (Orazem in sod., 2011b, 2011c).

Pri določenih podlagah so tla leta 2008 in 2009 vplivala na vsebnost suhe snovi. Pri vseh podlagah, pri katerih smo zaznali značilne razlike med tlemi, smo večje vsebnosti suhe snovi izmerili v plodovih dreves, ki so bila posajena na deviških tleh (Orazem in sod., 2011a).

Leta 2009 smo ugotovili značilno interakcijo med sorto in podlago, kar kaže na nestalen vpliv podlag na vsebnost suhe snovi. Interakcija je bila posledica odsotnosti statistično značilnih razlik v vsebnosti suhe snovi med podlagami, cepljenimi s sorto ‘Redhaven’, in prisotnosti razlik pri sorti ‘Royal Glory’. Dejstvo je, da je skoraj nemogoče določiti enako stopnjo zrelosti dveh različnih sort, kar bi lahko vplivalo na interakcijo (Orazem in sod., 2011c). Prav tako je lahko na interakcijo in različne vsebnosti suhe snovi vplivala različna stopnja zrelosti plodov pri obravnavanih podlagah. Leta 2009 med sortama nismo zabeležili statistično značilnih razlik v vsebnosti suhe snovi.

Z analizo variance smo leta 2008 ugotovili značilne razlike v vsebnosti suhe snovi med posameznimi podlagami pri sorti ‘Redhaven’ (Orazem in sod., 2011b). V poglavju o zorenju smo, na osnovi trdote in *a**-parametra osnovne barve, določili tri skupine podlag, ki so imele podoben vpliv na zorenje plodov (Orazem in sod., 2011a). Pregled obojih rezultatov pokaže, da je večina podlag (‘Barrier 1’, ‘Cadaman’, sejanec in ‘MrS 2/5’) v skupini, ki je vplivala na hitrejše dozorevanje plodov ter manjšo vsebnost suhe snovi, kar je v nasprotju s pričakovanji. Nasprotno smo v plodovih večine podlag iz skupine podlag, ki so vplivale na počasnejše zorenje (‘Adesoto’, ‘Julior’, ‘Tetra’), izmerili veliko vsebnosti suhe snovi. Iz tega lahko sklepamo, da ima podlaga večji vpliv na vsebnost suhe snovi kot sama stopnja zrelosti plodov.

3.1.4 Vpliv podlage, tal in sorte na vsebnost sladkorjev in organskih kislin

V plodovih obeh sort smo določali vsebnosti primarnih metabolitov. Določili in ovrednotili smo te ogljikove hidrate: saharozo, fruktozo, glukozo in sorbitol. Med organskimi kislinami smo potrdili in ovrednotili jabolčno, citronsko, fumarno in šikimsko kislino.

Med letoma 2008 in 2009 smo pri sorti ‘Redhaven’ opazili velike razlike v vsebnostih vseh sladkorjev, razen sorbitola. Te razlike bi lahko pripisali vremenskim vplivom posameznega leta, saj smo leta 2009 med rastno dobo izmerili ekstremno majhno količino padavin. Drugo možno razlago pa bi lahko iskali v manjši obremenjenosti dreves leta 2008. Tudi pri primerjavi naših izmerjenih vsebnosti z nekaterimi predhodnimi raziskavami (Byrne in sod., 1991; Genard in Souty, 1996; Colaric in sod., 2005), lahko ugotovimo, da vsebnosti sladkorjev zabeležene leta 2008, izstopajo.

Podlage so pri sorti ‘Redhaven’ vplivale na razlike v vsebnosti posameznih sladkorjev tako leta 2008 (Orazem in sod., 2011b) kot leta 2009 (Orazem in sod., 2011c). Z uporabo dvosmerne analize variance smo ugotovili značilno interakcijo med sorto in podlago pri glukozi, fruktozi in saharozi, ne pa tudi pri sorbitolu in skupnih sladkorjih. Tudi ta podatek kaže na podoben pojav kot pri masi plodov in vsebnosti suhe snovi. Podlage pri sortah ‘Redhaven’ in ‘Royal Glory’ niso imele enakega vpliva na vsebnost naštetih posameznih sladkorjev. Podlaga ‘Penta’ je pri sorti ‘Redhaven’ vplivala na veliko vsebnost glukoze, fruktoze in saharoze, kar bi lahko pripisali stopnji zrelosti, saj je ta podlaga leta 2009 vplivala na hitrejše dozorevanje plodov. Pri podlagah 'Ishtara' in sejanec smo izmerili majhno vsebnost glukoze, fruktoze in saharoze, kljub temu, da smo za podlago sejanec ugotovili, da vpliva na hitrejše dozorevanje plodov v primerjavi z drugimi podlagami. Pri sorti 'Royal Glory' je podlaga 'GF 677' vplivala na večje vsebnosti glukoze, fruktoze in saharoze, medtem ko smo, enako kot pri sorti 'Redhaven', pri sejancu izmerili majhno vsebnost glukoze in fruktoze. Vsebnost sorbitola in skupnih sladkorjev je bila večja v plodovih sorte 'Royal Glory' ne glede na podlago, zaradi česar interakcija ni bila statistično značilna (Orazem in sod., 2011c).

V plodovih obeh sort smo leta 2009 izmerili primerljive vsebnosti posameznih sladkorjev, vendar je sorta značilno vplivala na vsebnosti določenih posameznih sladkorjev. Pri obeh sortah so bile povprečne vsebnosti saharoze med 45 g/kg in 60 g/kg, kljub temu pa so bile med sortama statistično značilne razlike v vsebnosti saharoze v prid sorti 'Royal Glory'. O podobni vsebnosti saharoze v plodovih breskve poročajo tudi Colaric in sod. (2005) ter Genard in Souty (1996). V plodovih sorte 'Royal Glory' smo izmerili značilno večjo vsebnost glukoze, fruktoze in sorbitola kot pri sorti 'Redhaven'. Posledično se je med sortama razlikovala tudi vsebnosti skupnih sladkorjev (Orazem in sod., 2011c).

Podobno kot pri sladkorju smo tudi pri organskih kislinah leta 2008 izmerili večjo vsebnost kot leta 2009. Možne razloge za ta pojav smo že navedli v razpravi o sladkorjih. Vsebnosti izmerjene leta 2009 so primerljive z navedbami Byrne in sod. (1991), vendar manjše, kot jih pri drugih sortah navajajo Colaric in sod. (2005).

Pri vseh organskih kislinah je bila interakcija med podlago in sorto statistično značilna. V primerjavi s sorto 'Royal Glory' smo leta 2009 v plodovih sorte 'Redhaven' izmerili značilno večje vsebnosti jabolčne ter šikimske kisline, skupnih organskih kislin in manjše vsebnosti citronske kisline. Manjše vsebnosti organskih kislin v plodovih sorte 'Royal Glory' se kažejo v okusu, saj to sorto na podlagi organoleptičnih lastnosti pogosto ocenjujejo kot manj okusno v primerjavi s sorto 'Redhaven'.

Iz rezultatov lahko razberemo, da imajo podlage vpliv na primarne metabolite, vendar so le-ti odvisni tudi od številnih drugih dejavnikov, ki smo jih opazovali, ne pa tudi uravnavali. K razlikam pa so zelo verjetno doprinesle tudi različne stopnje zrelosti plodov. Zato bi bilo smiselno pri vseh podlagah obrati plodove v enaki stopnji zrelosti, s čimer bi lahko natančneje ovrednotili vpliv podlag na vsebnosti primarnih metabolitov.

3.1.5 Vpliv podlage, tal in sorte na vsebnost sekundarnih metabolitov

Med sekundarnimi metaboliti smo v obeh letih iz skupine hidroksicimetnih kislin v mesu in kožici določili neoklorogensko in klorogensko kislino, le v kožici pa še naslednje flavonole: kvercetin 3-O-galaktozid, kvercetin 3-O-rutinozid, kvercetin 3-O-glukozid kvercetin 3-O-ramnozid, ter antociana: cianidin 3-O-glukozid in cianidin 3-O-rutinozid (Orazem in sod., 2011b, 2011c). Tomás-Barberán in sod. (2001) v plodovih različnih sort breskve z izjemo p-kumarne kisline in kvercerin 3-O-galaktozida poročajo o enakih fenolnih snoveh. V primerjavi z njihovimi navedbami smo ugotovili velike razlike v vsebnostih neoklorogenske in klorogenske kisline.

Pri primerjavi let 2008 in 2009 smo ugotovili, da so bile leta 2009 vsebnosti vseh fenolnih snovi pri sorti 'Redhaven' večje (Orazem in sod., 2011b, 2011c). Največje razlike smo opazili pri antocianih, kjer smo v letu 2009 izmerili skoraj trikratno vrednost cianidin 3-O-glukozida v primerjavi z letom 2008. Razlike so najverjetneje posledica različnih klimatskih in/ali različne obremenjenosti dreves. Višje nočne temperature zraka povzročijo intenzivnejše dihanje in s tem večjo porabo sladkorjev, ki so vhodna snov za tvorbo antocianov. Tudi naši rezultati tako potrjujejo, da ima lahko leto velik vpliv ne le na zunanji izgled (vsebnost barvil), ampak tudi notranjo kakovost plodov, o čemer poročajo tudi Mikulič Petkovšek in sod. (2009).

V raziskavi iz leta 2009 je bila interakcija med sorto in podlago za hidroksicimetni kislini tako v mesu kot v kožici statistično značilna (Orazem in sod., 2011c). Pri obeh proučevanih sortah smo, podobno kot pri primarnih, tudi pri sekundarnih metabolitih zabeležili različen vpliv podlag na njihovo vsebnost. Določene razlike bi lahko bile tudi posledica sortno značilnih dejavnikov, kot na primer obarvanosti plodov, vegetativna rast in z njo povezana količina listne mase. Eden od možnih razlogov pa bi lahko bila tudi različna zrelost plodov.

Pri obeh sortah smo večje vsebnosti hidroksicimetnih kislin izmerili v kožici plodov, kar so ugotovili tudi Tomás-Barberán in sod., 2001. Pri vsebnostih flavonolov in prevladujočega antociana (cianidin 3-O-glukozida) nismo ugotovili statistično značilne interakcije med sorto in podlago. Vsebnosti kvercetin 3-O-rutinozida in kvercetin 3-O-glukozida so bile med sortama podobne, medtem ko sta bila druga dva flavonola in cianidin 3-O-glukozid pri sorti 'Royal Glory' prisotna v značilno manjših vsebnostih. Vsebnosti antocianov so bile v kožici sorte 'Royal Glory' nižje kot v sorti 'Redhaven', kar je v nasprotju z našimi pričakovanji, saj slednja v primerjavi s prvo velja za bolj obarvano.

Pri sorti 'Redhaven' smo leta 2008 pri posameznih podlagah zabeležili različne vsebnosti določanih sekundarnih metabolitov. Podobno smo vpliv podlag zabeležili tudi leta 2009, in sicer pri analizi hidrokiscimetnih kislin v mesu in kožici, antocianih v kožici, medtem ko pri analizi flavonolov v kožici vpliva nismo ugotovili. V plodovih sorte 'Royal Glory', cepljeni na različne podlage, smo ugotovili različne vsebnosti vseh hidroksicimetnih kislin v mesu in kožici, razen neoklorogenske kisline ter kvercetin 3-O-glukozida v kožici. Drugi flavonoli in oba antociana se nista statistično razlikovala.

Na osnovi naših rezultatov lahko povzamemo, da imajo podlage velik vpliv na rast drevesa na eni ter pridelek in njegovo kakovost, na drugi strani.

3.2 SKLEPI

V dvoletnem poskusu smo podrobno proučili vplive različnih podlag na rast dreves, pridelek, zorenje in pomološke lastnosti ter kemično sestavo plodov sort breskve 'Redhaven' in 'Royal Glory'. S tekočinsko kromatografijo visoke ločljivosti (HPLC) smo v užitni zrelosti izmerili vsebnosti ogljikovih hidratov (saharoze, glukoze, fruktoze in sorbitola), organskih kislin (citronske, jabolčne, fumarne in šikimske kisline) ter fenolnih snovi v mesu (neoklorogenska, klorogenska in p-kumarna kislina) in kožici (neoklorogenska in klorogenska kislina, kvercetin 3-O-galaktozid, kvercetin 3-O-glukozid, kvercetin 3-O-rutinozid, kvercetin 3-O-ramnozid, cianidin 3-O-glukozid in cianidin 3-O-rutinozid).

Podlage so pri obeh sortah vplivale na bujnost dreves, in sicer je bil vpliv posameznih podlag pri obeh sortah zelo podoben. Sorta 'Royal Glory' je bila bujnejša od sorte 'Redhaven'. Na utrujenih tleh smo bujno rast dreves ugotovili pri podlagah 'Monegro', 'Barrier 1', 'GF 677' in 'Adesoto', srednje bujno rast pri podlagah 'Julior' (šibkejša pri sorti 'Royal Glory'), sejanec (bujnejša rast pri sorti 'Royal Glory'), 'Tetra' in 'Penta', šibko pa pri podlagi 'Ishtara'. Podlaga 'MrS 2/5' je pri sorti 'Redhaven' vplivala na bujno, pri sorti 'Royal Glory' pa na šibko rast dreves. Na bujnost dreves so vplivala tudi tla.

Sorta 'Redhaven' je bila bolj rodna kot sorta 'Royal Glory', pridelek pa se je v drugem rodnem letu povečal. Podlage v drugem rodnem letu niso vplivale na količino pridelka.

Podlage so vplivale na zorenje plodov, vpliv pa ni bil odvisen od tal. Na deviških tleh je podlaga 'Julior' v obeh letih vplivala na počasnejše dozorevanje plodov, podlaga 'Barrier 1' pa je v obeh letih na obeh tleh vplivala na hitrejše dozorevanje plodov.

Masa plodov se je bila pri sorti 'Redhaven' leta 2009 večja kot leta 2008, med sortama pa se ni razlikovala. Podlage so vplivale na povprečno maso plodov. Pri sorti 'Redhaven' vpliva tal na maso plodov nismo ugotovili.

Med leti se je vsebnost suhe snovi razlikovala, prav tako smo pri sorti 'Redhaven' na utrujenih tleh izmerili značilno manjšo vsebnost suhe snovi kot na deviških tleh.

Leto, sorta in podlaga vplivajo na vsebnosti primarnih in sekundarnih metabolitov. Prav tako vpliva tudi zrelost plodov, zato bi primerjava zunanjih in notranjih lastnosti enako zrelih plodov prispevala k natančnejšemu ovrednotenju vpliva podlage na vsebnost primarnih in sekundarnih metabolitov.

Pri tretji generaciji breskovega sadovnjaka nismo opazili učinkov utrujenih tal, saj je na tleh, ki smo jih označili kot utrujena tla, propadlo manj dreves. Prav tako pa je bila njihova rast bujnejša od rasti dreves posajenih na deviških tleh.

V plodovih obeh sort je med ogljikovimi hidrati prevladovala saharoza, med organskimi kislinami jabolčna, med fenolnimi snovmi v mesu klorogenska kislina, v kožici pa med hidroksicimetnimi kislinami neoklorogenska, med flavonoli kvercetin 3-O-rutinozid in med antociani cianidin 3-O-glukozid.

Vsebnosti večine primarnih in sekundarnih metabolitov so se razlikovale tako med leti kot tudi med sortama. Pri posamezni sorti so znotraj posameznega leta podlage vplivale na vsebnosti primarnih in sekundarnih metabolitov. Kljub značilnemu vplivu podlag na parametre notranje kakovosti, pa ta vpliv pri sortah ni bil podoben.

Dvoletni rezultati našega poskusa nam sicer ne omogočajo zanesljivega priporočila katere podlage so najprimernejše za deviška oziroma utrujena tla. Kljub temu lahko zaključimo, da so drevesa cepljena na šibko podlago 'Ishtara', srednje šibki podlagi 'Penta' in 'Tetra' ter bujno podlago 'Adesoto' na utrujenih tleh propadala v manjšem številu, hkrati pa imela bolj kakovostne plodove. Na deviških tleh pa so imele najboljše rezultate šibka podlaga 'Ishtara', srednje šibka podlaga 'Tetra' ter bujna podlaga 'Monegro'.

Določitev stopnje utrujenosti tal ter spremljanje okoljskih dejavnikov, ki neposredno vplivajo na sintezo primarnih in sekundarnih metabolitov, pa bi omogočila natančnejše ovrednotenje vpliva podlag na vsebnost primarnih in sekundarnih metabolitov.

4 POVZETEK (SUMMARY)

4.1 POVZETEK

Breskev je v primerjavi z drugimi sadnimi vrstami zanimiva predvsem zaradi razmeroma zgodnjega začetka zorenja in obiranja plodov. V Sloveniji jo tradicionalno pridelujemo v Vipavski dolini, Goriških brdih in delih slovenske Istre ter tudi nekaterih nižje ležečih delih Štajerske in Dolenjske. Izbira podlage predstavlja eno od najpomembnejših odločitev tako pri napravi novega kot pri obnovi starega nasada ter sadjarjem omogoča razmeroma prožen in najcenejši način kontrole bujnosti dreves. Slovenski sadjarji so za napravo prve generacije breskovega sadovnjaka uporabljali sejanec breskve in za njim podlago ‘GF 677’, ki je križanec breskve in mandlja. Naš namen je bil zaznati vpliv različnih podlag na posamezne parametre zunanje in notranje kakovosti plodov.

V Sadjarskem centru Bilje smo leta 2008 in 2009 spremljali pridelek, bujnost in nekatere parametre kakovosti plodov breskve sorte ‘Redhaven’, leta 2009 pa tudi sorte ‘Royal Glory’ na deviških in utrujenih tleh. Proučevali smo enajst različnih podlag (‘Adesoto’, ‘Barrier 1’, ‘Cadaman’, ‘GF 677’, ‘Julior’, ‘Ishtara’, ‘MrS 2/5’, ‘Monegro’, ‘Penta’, sejanec in ‘Tetra’), ki so bile spomladi leta 2005 zasajene na stalno mesto na razdalji 4 × 2 m. Sorti smo na podlage cepili avgusta 2005. Vsako leto smo izmerili obsege debla 20 cm nad cepljenim mestom, pridelek po drevesu, na plodovih opravili meritve pomoloških lastnosti (masa, trdota in obarvanost plodov ter vsebnost suhe snovi) ter jih nadgradili s HPLC-analizami primarnih in sekundarnih metabolitov.

Leta 2008 smo ugotovili vpliv podlag na maso plodov pri sorti ‘Redhaven’. Najverjetneje je do razlik prišlo zaradi različnih pridelkov. Podlaga ‘Julior’ je vplivala na večjo maso plodov, medtem ko smo pri podlagi ‘Barrier 1’ in ‘GF 677’ izmerili lažje plodove. Podlage so vplivale tudi na zorenje plodov. Leta 2008 je podlaga ‘Julior’ na utrujenih tleh vplivala na zgodnejše zorenje sorte ‘Redhaven’, medtem ko je podlaga ‘Monegro’ zorenje podaljšala. Leta 2009 je podlaga ‘Julior’ vplivala na poznejše zorenje plodov na deviških tleh, na utrujenih tleh pa v obeh opazovanih letih. Plodovi dreves, cepljenih na podlagi ‘Adesoto’, so bili najboljše kakovosti, saj smo v njih izmerili velike vsebnosti suhe snovi, posameznih in skupnih sladkorjev, organskih kislin, v mesu pa tudi fenolnih snovi. Poleg tega smo pri tej podlagi ugotovili tudi velik pridelek. Plodove dobre kakovosti (velika vsebnost suhe snovi ter posameznih in skupnih sladkorjev) smo obrali tudi na drevesih posajenih na podlago ‘Julior’. Podlagi ‘Cadaman’ in sejanec sta negativno vplivali na kakovost plodov sorte ‘Redhaven’, kar se je izkazalo v majhnih vsebnostih sladkorjev, organskih kislin in fenolnih snovi v mesu in kožici.

Na deviških tleh so bili plodovi ne glede na podlago boljše notranje kakovosti (večje vsebnosti suhe snovi in skupnih sladkorjev) kot na utrujenih tleh. ‘Barrier 1’, ‘GF 677’ in sejanec so dale dobre rezultate na deviških tleh, medtem ko so se na utrujenih tleh za najboljše podlage izkazale ‘Adesoto’, ‘Tetra’ in ‘Penta’.

Podlage so imele podoben vpliv na bujnost rasti dreves obeh sort. Podlaga 'Ishtara' je vplivala na šibko rast dreves, podlage 'Adesoto', 'Penta' in sejanec na srednje bujno in podlage 'Barrier 1', 'GF 677' in 'Monegro' na bujno rast dreves. Pri sorti 'Redhaven' smo izmerili večji pridelek na drevo v primerjavi s sorto 'Royal Glory', medtem ko podlage niso vplivale na pridelek posamezne sorte v drugem rodnem letu. Pri sorti 'Redhaven' podlage niso vplivale na vsebnost suhe snovi, medtem ko smo značilen vpliv zabeležili pri sorti 'Royal Glory'. Največje vsebnosti suhe snovi pri sorti 'Royal Glory' smo leta 2009 zabeležili v plodovih dreves cepljenih na podlago 'Penta', medtem ko smo v plodovih drevesih, cepljenih na podlago 'Adesoto' in 'Monegro', izmerili majhne vsebnosti. V plodovih obeh sort smo ugotovili razlike v vsebnosti primarnih in sekundarnih metabolitov, značilen pa je bil tudi vpliv podlag na notranjo kakovost plodov posamezne sorte. Ta vpliv je bil najvidnejši pri hidroksicimetnih kislinah v mesu in kožici. Pri analizi flavonolov in prevladujočega antociana cianidin 3-O-glukozida smo ugotovili enoten vpliv podlag pri obeh sortah. Ugotovili smo tudi, da so se fenolne kisline v mesu in kožici pri obeh sortah bolj spreminjale, kot so se spreminjali ostali sekundarni metaboliti.

Na osnovi naših rezultatov lahko trdimo, da podlaga občutno vpliva na velikost drevesa in njegov pridelek. Na kakovost plodov zelo vplivajo različni okoljski dejavniki, ki pa jih je v sadovnjaku nemogoče izenačiti in se iz leta v leto lahko precej spreminjajo. Zaradi vsega naštetega je vpliv teh dejavnikov na kakovost plodov težko ovrednotiti. Z vključitvijo podrobnejših analiz tal, natančnejšim ovrednotenjem stopnje utrujenosti tal in z meritvami okoljskih parametrov, ki neposredno vplivajo na biokemijske parametre plodov, pa bi učinke podlag lahko ovrednotili bolj natančno. Dodatno bi k temu prispevalo tudi to, da bi poskus izvajali več rodnih let, s čimer bi lažje identificirali ponavljajoče se vplive podlag. Raziskavo bi bilo v istem obsegu pri drevesih v polni rodnosti smiselno spremljati še nekaj let, saj je pridelek drevesa v tem življenjskem obdobju veliko bolj konstanten kot v prvih letih rodnosti.

4.2 SUMMARY

Peach is an interesting fruit species from production point of view because of early ripening in comparison with other fruit species. Vipava valley, Goriška brda, parts of Slovenian Istria as well as lower parts of Styria and Lower Carniola are the main regions of the Slovenian peach production. The selection of rootstock is one of the most important considerations when designing a new orchard or when replanting an old one since it enables the fruit grower relatively flexible and cheap way to control the tree size. In Slovenia peach seedling rootstock was used for the plantation of new orchards, which was replaced with 'GF 677' (almond × peach) rootstock. Our aim was to detect the influence of different rootstocks on vigor, yield as well as internal and external fruit quality.

The experiment was conducted in the Fruit Growing Centre Bilje near Nova Gorica in 2008 and 2009 at cv. 'Redhaven' and at cv. 'Royal Glory' in year 2009. Yield, vigor and several quality parameters were monitored. Eleven different rootstocks ('Adesoto', 'Barrier 1', 'Cadaman', 'GF 677', 'Julior', 'Ishtara', 'MrS 2/5', 'Monegro', 'Penta', peach

seedling and 'Tetra') were tested. Rootstocks were planted to the permanent place in the spring 2005 with 4×2 m tree spacing. Grafting was performed in August 2005. Each year trunk circumference was measured 20 cm above graft union. At harvest all fruit from an individual tree were collected at each picking time to determine yield per tree. Fruit were weighed and soluble solids, ground color, and fruit firmness were measured. Primary and secondary metabolites were analyzed with HPLC.

At cv. 'Redhaven' rootstocks influenced differences in fruit weight in 2008. These differences were most likely affected by different yields. 'Julior' rootstock had the heaviest fruit, while 'Barrier 1' and 'GF 677' produced lighter fruit. Rootstocks influenced harvest maturity. 'Monegro' produced the least ripe fruit. On the other hand 'Julior' rootstock influenced early ripening of 'Redhaven' in replant soil in 2008. 'Julior' rootstock delayed ripening in virgin soil in 2008 and in both soils in 2009. 'Adesoto' rootstock resulted in the best overall fruit quality (high values of soluble solids content, individual and total sugar content, individual and total organic acids and phenolic compounds in pulp) as well as high total yield. 'Julior' rootstock also produced good quality peach (high values of soluble solids content, individual and total sugars). 'Cadaman' and peach seedling rootstock produced 'Redhaven' fruit of the lowest quality, indicated by low values of sugars, organic acids, and phenolic compounds in pulp and in skin.

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. Rootstocks 'Adesoto', 'Tetra', and 'Penta' showed the greatest potential for replant soil.

A uniform effect of rootstock on tree size was evident at both cultivars. The 'Ishtara' rootstock induced weak tree growth; 'Adesoto', 'Penta' and peach seedling semi vigorous growth; and 'Barrier 1', 'GF 677', and 'Monegro' vigorous tree growth. Higher yields were recorded at cv. 'Redhaven' compared to 'Royal Glory', while no significant differences in yield in the fourth growing season were found among the rootstocks for each cultivar. Rootstocks had no effect on soluble solids at cv. 'Redhaven', while at 'Royal Glory' they did. 'Penta' rootstock influenced highest soluble solids content at cv. 'Royal Glory', while 'Adesoto' and 'Monegro' were associated with low contents. In the fruit from both cultivars, the rootstock had a significant influence on individual sugars, organic acids, and phenolic acids in the pulp. The influence of rootstocks on internal fruit quality of each cultivar was also evident. This influence was the greatest at hidroksicinnamic acids in flesh. Flavonols and the most abundant anthocyanin (cyanidin 3-O-glucoside) were affected uniformly by rootstocks. We also found that phenolic acids in the pulp and skin were more affected by the rootstock than other secondary metabolites analyzed, regardless of the cultivar.

On the basis of our results we can claim that rootstocks have effect on peach tree and on its yield. It is impossible to equalize environmental effects and assess their influence on fruit quality since conditions differ among the years. Addition of detailed pedological analysis and more accurate assessment of soil sickness as well as with environmental factors that directly influence biochemical properties of the fruit we would more accurately evaluate the influence of the rootstocks. We would additionally contribute to these information if evaluate the results of several growing seasons to identify reoccurring effect of the rootstock. It would be sensible to repeat the investigation in several full bearing seasons since in this period of the tree life the yield is much more constant compared to first bearing years.

5 VIRI

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PRILOGA A

Število propadlih dreves pri breskvah sorte ‘Redhaven in ‘Royal Glory’ na različnih podlagah na deviških in utrujenih tleh do leta 2009; Bilje, 2009

Number of perished trees at peach cvs. ‘Redhaven and ‘Royal Glory’ grafted on different rootstocks on virgin and replant soil until 2009; Bilje, 2009

Sorta/Cultivar	‘Redhaven’		‘Royal Glory’	
Podlaga/Tla Rootstock/Soil	Deviška Virgin	Utrujena Replant	Deviška Virgin	Utrujena Replant
‘GF 677’	0	3	6	0
‘Sejanec’ / peach seedling	3	1	3	2
‘Monegro’	0	2	0	2
‘Barrier 1’	1	3	3	1
‘Cadaman’	3	2	4	1
‘Adesoto’	3	1	1	1
‘MrS 2/5’	3	2	4	0
‘Julior’	8	2	2	3
‘Ishtara’	0	0	1	0
‘Penta’	3	0	1	0
‘Tetra’	1	1	1	0