Growth, phenology and fruit set of *Prunus armeniaca* L. (cv. Ninfa) grafted on two rootstocks in organic and conventional management

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Abstract

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Tree growth, flowering, yield and fruit quality of *Prunus armeniaca* L. cv. Ninfa grafted on peach cv. Nemaguard [*Prunus persica* (L.) Batsch] and cv. Real Fino apricot (*Prunus armeniaca* L.) as rootstocks were analysed in experimental orchard under organic and conventional management systems. The study was performed during 2012–2013 in the province of Seville (SW Spain). Cv. Nemaguard rootstock had larger cross-sectional areas of the trunk (TCSA), higher yields, began flowering earlier and lasted 2–4 days more. The organic management resulted in lower values of TCSA and yield, and flowering was delayed and shortened. Overall, cv. Nemaguard rootstock produced slightly larger fruit in size and heavier weight. In contrast, apricots from cv. Real Fino had slightly higher soluble solid concentration. Acidity and maturity index were similar, while colour and firmness showed high variability. In general, the organic system produced fruit with soluble solid concentration somewhat higher. In summary, in both types of management cv. Nemaguard worked better than cv. Real Fino in terms of tree vigour, fruit yield and bloom period.

Keywords: apricot; fruit quality; yield; tree growth; flowering

Apricot (*Prunus armeniaca* L.) is the second most important species within stone fruit in Spain, although far behind the peach. Spain and Italy are the largest producers in the European Union; the surface in Spain, around 25,000 ha, is mostly located in the regions of Murcia (over 50%) and Valencia (25%) while in other areas of Spain the surface is smaller. In Andalusia, a large region with significant production of stone fruit, there are barely 150 ha of apricot culture. Still there is no surplus cultivation in the European Union, with interesting possibilities for future expansion. In Spain there are two important limitations for apricot crop expansion: first, Sharka disease, caused by the *Plum pox virus*, which was forced to boot more than one million of affected trees (Badenes et al. 2004) and, secondly, the large swings or production problems presented by most of cultivars when they move from one region to another (Layne et al. 1996). It is known that many of these issues stem from problems of self-incompatibility and other aspects of the floral biology of this species, which is also very sensitive to weather conditions (Burgos et al. 2004; Rodrigo, Hormaza 2005). Therefore, productions are centred in very few cultivars, particularly cv. Búlida (Murcia) and cv. Canino (Valencia). Although breeding programs

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and studies of cultivar adaptation have been going on for several years, there is still a long way to go in this regard (Alburquerque et al. 2002; Badenes, Llácer 2006; Milatović et al. 2013).

Rootstocks are essential to optimize the anchorage to the ground, for intake of water and nutrients, to resist or tolerate soil pathogens and may also affect other trees and fruit characteristics such as vigour, flowering, fruit size or sugar content, among others (Hernández et al. 2010; Milosevic et al. 2011; Sitarek, Bartosiewicz 2011). Rootstocks may also significantly determine the response to organic farming system in which fertilization is based solely on the input of organic fertilizers, especially manure and groundcovers with legumes.

A few years ago, in an experimental orchard established in the south of Spain it was preliminary observed that the apricot cv. Ninfa (Ouardi × Tirynto, University of Bologna, 1981) could have a good agronomic performance in the region. Characteristics such as early ripening and good yield of this cultivar (Sottile et al. 2006; Lo Bianco et al. 2010) suggest that it could be of interest in areas suitable for early production such as Andalusia. In the present work, the behaviour of this cultivar, grafted on two different rootstocks was evaluated and subjected to conventional or organic agricultural management. Data on tree vigour, flowering, fruit yield and quality are shown.

MATERIAL AND METHODS

Plant material and trial characteristics. *Prunus armeniaca* L. cv. Ninfa grafted on peach cv. Nemaguard [*P. davidiana* (Carr.) Franch × *P. persica* (L.) *Batsh.*] and cv. Real Fino apricot seedling (*P. armeniaca* L.) was used in this work. All the trees were planted in January 2009 as bare root one-year-old trees grafted onto both rootstocks. The study was conducted during 2012–2013 in two similar experimental plots located at the IFAPA Centro "Las Torres-Tomejil" in the province of Seville in the Guadalquivir River Valley (SW Spain) (37°30'48"N; 5°57'46"W). In both orchards, the experiment was designed as randomised block design with three replications, each containing 6 trees of cv. Ninfa cultivar on each rootstock. The plots, 150 m apart to avoid interference in the different management systems, were located at an altitude of 11 m a.s.l. on a loam soil classified as a Xerofluvent (Baillie 1999). Each experimental plot was subjected to two different types of management, organic versus conventional management. The region has a Type C Mediterranean climate, according to the Köppen classification (Peel et al. 2007).

Fertilization and other major field works in both orchards. Fertilization in the organic plot was applied annually with animal manure at a dose of 3 kg/m^2, representing an approximate input of 140 units of nitrogen (N), 40 of phosphorus (P) and 148 of potassium (K). Furthermore, green covers of beans and oats + vetch, alternatively each year, were sown in November and buried in February. The conventional plot received applications of mineral fertilizers, including complex formulations (11:11:11), ammonium nitrate and potassium sulphate to 150 units of N, 55 of P and 150 of K. Both orchards were similarly irrigated by gravity along two rows parallel to the line of trees during the dry season. Each year, depending on climatic conditions, from 5 to 8 irrigations were applied (350,000 l/ha each). Land management consisted of reduced tillage. The planting framework was 4 m between trees and 5 m between rows. The trees were pruned to a vessel system, and care was taken to keep them at a similar height and width on both types of rootstock. The different pest and disease treatments in each plot were adjusted to regulations in integrated production (Real Decreto 1201/2002 and Decreto 245/2003) and in organic farming (Council Regulation, ECC 2992/91 and Council Regulation, EC 834/2007).

Tree growth and yield. Growth and vigour of the trees were evaluated at the end of the growing season in November 2012 and 2013 calculating the cross-section area of the trunk (TCSA) 20 cm above the graft (Layne 1994; Lepsis, Blanke 2006). The production was calculated taking into account the total fruit collected in all the trees on each rootstock.

Flowering. For flowering studies, data were taken from nine trees per rootstock (3 per block) and treatment. According to the BBCH scale (Hack et al. 1992), the following phenological periods were taken: opening of the first flowers, full flowering (> 50% flowers open), end of flowering (all petals fallen), and also the duration of flowering.

Fruit analysis. Twenty four fruits were collected from each of the six trees, fruits were picked from 1 to 2 m height and from each of the four cardinal points to avoid fruit position effect (Taylor et al. 1993). Eighteen apricots were randomly taken from each batch and were processed for quality analysis. Their size was determined using a digital slide gauge Mitutoyo CD-15CR

(Mitutoyo America Corp., Aurora, USA). Following the terminology proposed by Caillavet and Souty (1950), polar (∅P), suture (∅S) and equatorial (∅E) diameters were measured and transformed to the parameter denominated "size" defined as (∅P + ∅S + ∅E)/3. Fruit weight was determined using a digital scale Ohaus TP2000 (Ohaus Corp., Parsippany, USA). Fruit colour parameters *L**, *a** and *b** were measured with a Minolta colorimeter CR-300 (Minolta Co., Ltd., Osaka, Japan). Soluble solid concentration (°Bx) was determined using an ATAGO PR-101 digital refractometer (ATAGO Co. Ltd., Tokyo, Japan). Titratable acidity was determined on three juice samples (6 apricots each), diluted in distilled water, and microtitrated with NaOH 0.1 N. The ripeness index was calculated as the ratio of solid soluble concentration/acidity. Fruit firmness was tested with a penetrometer 53205 (T. R. Turoni srl, Forli, Italy).

Statistical analysis. Statistical analyses were performed using the Statistix software (vers. 9.0; NH Analytical Software, Tallahassee, USA). Single analysis of variance was used to analyse all the experimental data. Results were expressed at the $P < 0.05$ level of significance.

RESULTS AND DISCUSSION

Tree growth and yield

In 2012 and 2013 the TCSA values were significantly higher for cv. Nemaguard rootstock in both types of management (Table 1). In addition, for each rootstock, values were always higher in the conventional management, with significant differences for cv. Nemaguard. Similar results were observed with respect to fruit yield, confirming the higher performance on rootstock cv. Nemaguard, and being higher in the conventionally managed system for both rootstocks. In addition, the root system was evaluated and a higher number and larger roots for cv. Nemaguard were found (data not shown). As preliminary conclusion, it seems clear that in the south of Spain, and with this type of soil, cv. Nemaguard has better anchorage and higher tree development than cv. Real Fino, which also results in higher yields. Higher tree vigour and yields were found in conventionally managed systems compared to the organic ones; it is almost a constant, not only for fruit orchards, but also for most vegetables and cereals crops (De Ponti et al. 2011; Daza et al. 2012). Fruit production was higher in 2012, probably due to the high humidity and rainy weather registered along the flowering period in 2013 that made difficult fruit setting.

Flowering

Agroclimatic conditions registered in the zone during flowering and fruit set are shown in Fig. 1 and flowering periods in 2012 and 2013 are shown in Fig. 2. In 2012, this period was 1–2 days longer for cv. Nemaguard and also one (cv. Real Fino) or two days (cv. Nemaguard) longer in the conventionally managed orchard. In 2013, cv. Nemaguard had a flowering period 4–5 days longer than cv. Real Fino; yet, it was observed that for both rootstocks this period was 2–3 days longer in the conventionally managed system. Moreover, it was found that flowering was initiated 1–2 days earlier for both rootstocks in the conventional management, although cv. Nemaguard was 1–2 days ahead compared to cv. Real Fino. The mean duration of the flowering period was considerably

Table 1. Trunk cross-sectional areas (TCSA), fruit yield, fruit size and weight of cv. Ninfa grafted onto cvs Nemaguard (Nem) and Real Fino (RF) from organic (O) or conventionally (C) managed orchards in 2012 and 2013

	2012		2013		2012		2013	
	Nem	RF	Nem	RF	Nem	RF	Nem	RF
	TCSA (cm^2)				**Yield** (kg/tree)			
O	112.16[a]	70.12[b]	131.91[a]	84.06[b]	7.74[a]	1.12[b]	3.74[a]	0.96[b]
C	*182.57[a]	74.78[b]	*214.56[a]	98.15[b]	*32.56[a]	*17.09[b]	8.12[a]	3.87[a]
	Size (cm)				**Weight** (g)			
O	*48.22[a]	45.53[b]	45.03[a]	44.06[a]	*65.21[a]	49.63[b]	54.44[a]	49.23[a]
C	45.31[a]	43.89[b]	44.29[a]	43.52[a]	52.64[a]	50.03[a]	51.64[a]	47.89[a]

[a,b]in rows indicate significant difference between rootstocks for each type of management, parameter and year; *in columns indicates significant differences between management systems at $P < 0.05$

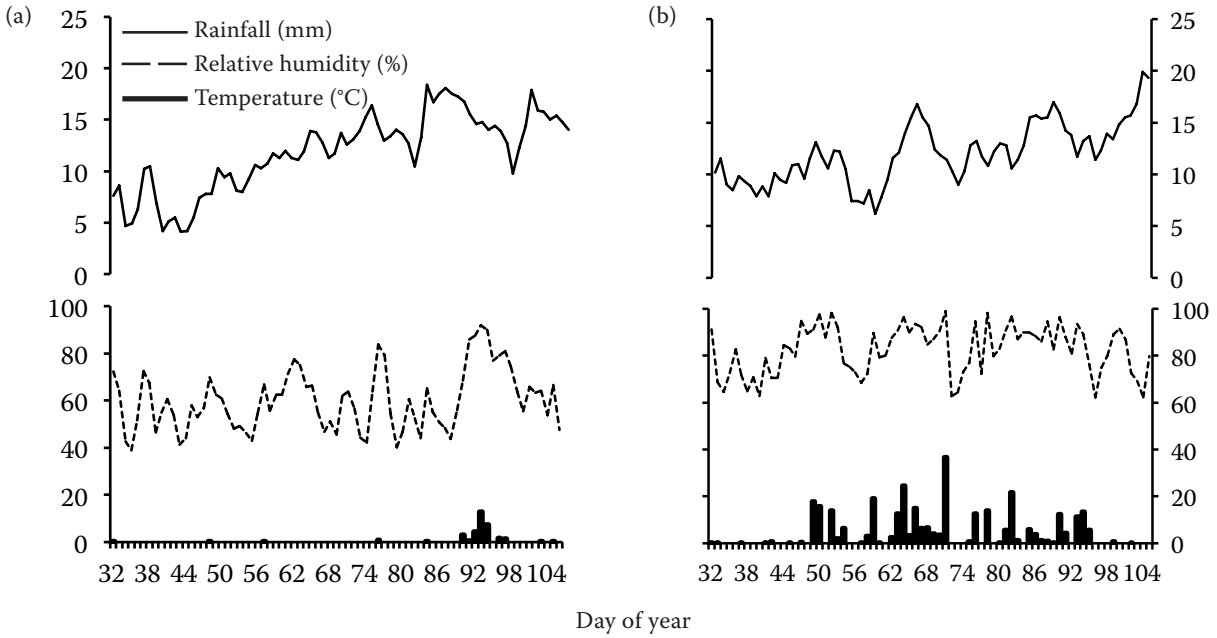

Fig. 1. Agroclimatic conditions registered in the study area during February–April in (a) 2012 and (b) 2013
relative humidity and temperature are daily mean values

higher in 2013 (26.75 days) than in 2012 (11.75 days). This shorter and more intense flowering period in 2012 was probably due to the higher number of chilling units during the winter of 2011/2012 (849 h below 7°C) compared with 2012/2013 (670 h below 7°C). The higher tree vigour could be correlated with earlier and longer flowering showed by rootstock cv. Nemaguard, as previously discussed. This may be an important factor to consider for species with pollination difficulties such as apricot. Moreover, a slight delay and shortening of flowering in organic systems over conventional was also previously observed in Japanese plum orchards (Arroyo et al. 2013). In summary, the phenological studies confirmed that cv. Nemaguard behaves better than cv. Real Fino.

Fruit quality

With regard to fruit size, trees grafted on cv. Nemaguard produced fruit slightly larger in all cases but only with a significant difference in 2012, for both organic and conventional management (Table 1). Consequently, fruit weights were also bigger on cv. Nemaguard, but showing a significant difference only in the organic plot in 2012. A slight decrease of both parameters for both rootstocks was observed from 2012 to 2013.

In fruit colour of apricots the parameters a^* and b^* could be a good reference, so lower values of both parameters are interpreted as more orange. Overall, a great variability of data was observed,

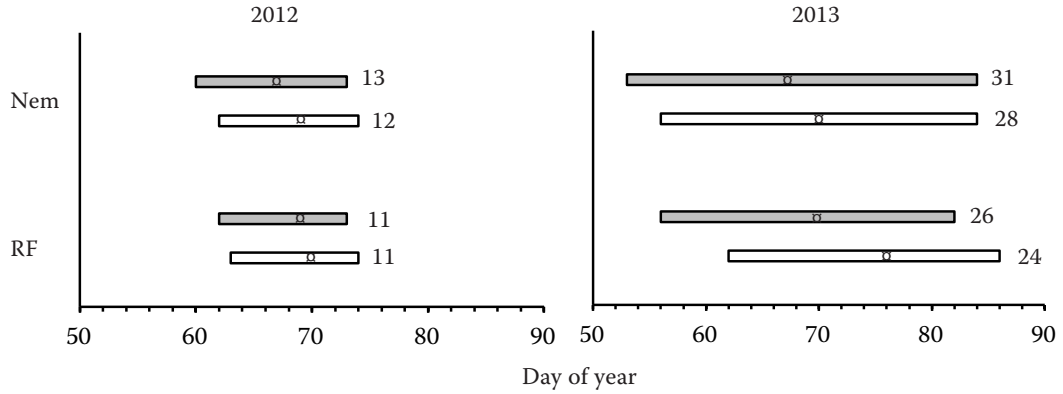

Fig. 2. Flowering period of cv. Ninfa grafted onto cvs Nemaguard (Nem) and Real Fino (RF) in both types of management in 2012 and 2013
numbers to the right of the bars indicate the duration of the flowering period ▩ conventional; □ organic and ¤ full bloom

Table 2. Colour parameters *a** and *b**, soluble solid concentration and titratable acidity, maturity index and firmness of cv. Ninfa grafted onto cvs Nemaguard (Nem) and Real Fino (RF) from organic (O) or conventionally (C) managed orchards in 2012 and 2013

	2012		2013		2012		2013	
	Nem	RF	Nem	RF	Nem	RF	Nem	RF
	Colour parameter *a**				**Colour parameter *b****			
O	*47.20[a]	40.52[b]	45.61[a]	*45.27[a]	16.12[a]	16.86[a]	18.48[a]	*17.91[a]
C	42.12[b]	*47.81[a]	45.88[a]	42.43[b]	*13.69[a]	15.19[a]	20.45[a]	15.30[b]
	Soluble solids (°Brix)				**Acidity** (g malic acid/100 ml)			
O	9.27[a]	*10.33[a]	10.10[b]	*11.60[a]	1.65[a]	1.75[a]	1.56[a]	1.56[a]
C	8.67[a]	9.13[a]	9.63[a]	10.40[a]	1.66[a]	1.71[a]	1.54[a]	1.45[a]
	Maturity index				**Firmness** (kg/cm^2)			
O	5.63[a]	5.91[a]	6.48[a]	7.45[a]	1.95[b]	*2.82[a]	*2.21[a]	1.69[a]
C	5.23[a]	5.39[a]	6.24[b]	7.16[a]	2.06[a]	1.89[a]	1.63[b]	*2.65[a]

[a,b]in rows indicate significant difference between rootstocks for each type of management, parameter and year; *in columns indicates significant differences between management systems at $P < 0.05$

without a defined and stable trend (Table 2). For example, in 2013, the rootstock cv. Real Fino in the conventional treatment produced fruit with lower values for *a** and *b**, a trend that was not clear for the organic treatment, neither in 2012.

Cv. Real Fino always showed total soluble solids concentration slightly higher than cv. Nemaguard, but with significant differences only in the organically managed orchard in 2013 (Table 2). In all cases values were higher in the organic plot, showing significant differences for cv. Real Fino rootstock in both years. Acidity did not show significant differences between both rootstocks and both types of management.

The maturity index showed significant differences neither between rootstocks, nor between the types of management (Table 2), showing higher values in 2013, since that year fruit was sweeter and with lower acidity. In contrast, firmness showed a great variability by year, rootstock or treatment, albeit oscillations were not relevant.

Fruit quality results obtained in this study indicate that there are no significant differences in using either rootstock. Moreover, it seems clear for this cultivar that fruit colour and flesh firmness are not suitable reference parameters as they vary greatly in short time, and show large oscillations between fruit surface. The rootstock cv. Real Fino produces fruit with soluble solid concentration somewhat higher, which would have relevance for a cultivar as early as cv. Ninfa, generally with low °Brix. Organic fruit had higher size, weight and soluble solid concentration, possibly due to the markedly lower yield in this type of management.

Results obtained in this study indicate that regardless of the type of management trees grafted on cv. Nemaguard showed an increased vegetative growth, probably due to a better root development allowing better soil anchoring and nutrients uptake in this type of soil and weather conditions. In addition the use of this rootstock resulted in a longer flowering period and a higher fruit production. The fruit on cv. Nemaguard had larger sizes and heavier weights, although with lower soluble solid concentrations. All trees grown in the organic management had reduced vigour, slightly delayed and somewhat shorter flowering as well as lower production.

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References

Alburquerque N., Egea J., Pérez-Tornero O., Burgos L., 2002. Genotyping apricot cultivars for self-(in)compatibility by means of Rnases associated with *S* alleles. Plant Breeding, *121*: 343–347.

Arroyo F.T., Jiménez-Bocanegra J.A., García-Galavís P.A., Santamaría C., Camacho M., Castejón M., Pérez-Romero L.F., Daza A., 2013. Comparative tree growth, phenology and fruit yield of several Japanese plum cultivars in two newly established orchards, organic and conventionally managed. Spanish Journal of Agricultural Research, *11*: 155–163.

Badenes M.L., Llácer G., 2006. Breeding for resistance: breeding for *Plum pox virus* resistant apricots (*Pruus armeniaca* L.) in Spain. EPPO Bulletin, *36*: 323–326.

Badenes M.L., Martínez-Calvo J., Llácer G., 2004. Estado actual del programa de mejora genética de albaricoquero (*Prunus armeniaca* L.) en la Comunidad Valenciana. [Current status of apricot breeding program (*Prunus armeniaca* L.) in Valencia region.] Fruticultura Profesional, *144*: 7–11.

Baillie I.C., 1999. Soil Survey Staff 1999, Soil Taxonomy: A basic system of soil classification for making and interpreting soil surveys, 2nd Ed. Agricultural Handbook 436, Natural Resources Conservation. Soil Use and Management, *17*: 57–60.

Burgos L., Alburquerque N., Egea N., 2004. Review. Flower biology in apricot and its implication for breeding. Spanish Journal of Agricultural Research, *2*: 227–241.

Caillavet H., Souty J., 1950. Monographie des principales variétés de pêches. ITEA, *37*: 18–26.

Commission Regulation 2992/91/ECC on the supply of various consignments of cereals as food aid. Official Journal of the European Communities, L 285 15/10/1991.

Council Regulation 834/2007 of 28 June 2007 on organic production and labelling of organic products and repealing Regulation (EEC) No. 2092/91. Official Journal of the European Union L 189 20/07/2007.

Daza A., Camacho M., Galindo I., Arroyo F.T., Casanova L., Santamaría C., 2012. Comparative fruit quality parameters of several Japanese plum varieties in two newly established orchards, organic and conventionally managed. International Journal Food Science and Technology, *47*: 341–349.

De Ponti T., Rijk B., Van Ittersum M.K., 2011. The crop yield gap between organic and conventional agriculture. Agricultural Systems, *108*: 1–9.

Decreto 245/2003 of Junta de Andalucía, Septiembre 2. Boletín Oficial de la Junta de Andalucía 174, 10/09/2003.

Hack H., Bleiholder H., Buhr L., Meier U., Schnock-Fricke U., Weber E., Witzenberger A., 1992. Einheitliche Codierung der phänologischen Entwicklungsstadien mono- und dikotyler Pflanzen–Erweiterte BBCH-Skala, Allgemein. Nachrichtenblatt des deutschen Pflanzenschutzdienstes, *44*: 265–270.

Hernández F., Pinochet J., Moreno M.A., Martínez J.J., Legua P., 2010. Performance of *Prunus* rootstocks for apricot in Mediterranean conditions. Scientia Horticulturae, *124*: 354–359.

Layne R.E.C., 1994. Prunus rootstocks affect long-term orchard performance of redhaven peach on brookston clay loam. Hortscience, *29*: 167–171.

Layne R.E.C., Bailey C.H., Hough L.F., 1996. Apricots. In: Janick J., Moore J.M. (eds.), Fruit Breeding Tree and Tropical Fruits. New York, John Willey and Sons: 79–111.

Lepsis J., Blanke M.M., 2006. The trunk cross-section area as a basis for fruit yield modelling in intensive apple orchards. Acta Horticulturae (ISHS), 707: 231–235.

Lo Bianco R., Farina V., Indelicato S.G., Filizzola F., Agozzino P., 2010. Fruit physical, chemical and aromatic attributes of early, intermediate and late apricot cultivars. Journal of the Science of Food and Agriculture, *90*: 1008–1019.

Milatović D., Nicolić D., Krška B., 2013. Testing of self-(in)compatibility in apricot cultivars from European breeding programmes. Horticultural Science (Prague), *40*: 65–71.

Milosevic T., Milosevic N. Glisic I., 2011. Influence of stock on the early tree growth, yield and fruit quality traits of apricot (*Prunus armeniaca* L.). Tarim Bilimleri Dergisi, *17*: 167–176.

Peel M.C., Finlayson B.L., Mc Mahon T.A., 2007. Updated world map of the Köppen-Geiger climate classification. Hydrology Earth System Sciences, *11*: 1633–1644.

Real Decreto 1201/2002 de Noviembre 20. Boletín Oficial del Estado 287, 30/11/2002.

Rodrigo J., Hormaza J.I., 2005. El albaricoquero. Diversidad genética y situación actual del cultivo. [The apricot. Genetic diversity and current situation.] Información Técnica Económica Agraria, *101*: 333–342.

Sitarek M., Bartosiewicz B., 2011. Influence of a few seedling rootstocks on the growth, yield and fruit quality of apricot trees. Journal of Fruit and Ornamental Plant Research, *19*: 81–86.

Sottile F., Monte M., Impallari F., 2006. Vegetative and reproductive behaviour of young apricot trees cv. 'Ninfa' as affected by rootstock. Acta Horticulturae (ISHS), 717: 79–82.

Taylor M.A., Rabe E., Dodd M.C., Jacobs G., 1993. Influence of sampling date and position in the tree on mineral nutrients, maturity and gel breakdown in cold stored songold plums. Scientia Horticulturae, *54*: 131–141.

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