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Influence of peach–almond hybrids and plum-based rootstocks on mineral nutrition and yield characteristics of 'Big Top' nectarine in replant and heavy-calcareous soil conditions

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ABSTRACT

The agronomic performance and leaf mineral nutrition for 'Big Top' nectarine budded onto twelve *Prunus* rootstocks were evaluated. Seven *Prunus amygdalus* × *Prunus persica* hybrids (Adafuel, Adarcias, Felinem, Garnem, Monegro, GF 677, and Mayor), two *Prunus davidiana* × *P. persica* hybrids (Barrier, Cadaman), a *Prunus insititia* plum (Adesoto), a *Prunus domestica* plum (Tetra), and another selection considered to be an hybrid of *Prunus cerasifera* × *P. amygdalus* parentage (Replantpac). Rootstocks were budded during the summer of 1999, and trees were established in a replant site in March 2001. The trial was located in the Ebro Valley (Northeastern, Spain) on a heavy-textured and calcareous soil typical of the Mediterranean area which supported a previous peach orchard until 2000. At the thirteenth year after budding, growing conditions generated varying levels of tree mortality, the highest with peach-almond hybrids: Adafuel, Garnem and Monegro. In contrast, all Replantpac trees survived well and the mortality rate was low on the other rootstocks. Adesoto, Tetra, and Adarcias proved to be the most dwarfing rootstocks, while Cadaman and Replantpac were the most invigorating and generated greater cumulative yields. However, the highest yield efficiency was recorded on GF 677, although it did not differ significantly from other peach-almond (Adarcias, Felinem) and plum (Adesoto, Tetra) rootstocks. The highest fruit weight was observed on Barrier and the lowest on Felinem and Mayor, but they did not differ significantly from the rest of rootstocks. Leaf mineral analysis of trees showed all rootstocks induced N and Fe deficiency and P optimum value according to reference values. Nevertheless, the tendency of plum Adesoto to induce higher Fe leaf concentration could indicate higher tolerance to iron-chlorosis in calcareous soils. The most invigorating rootstock Replantpac seems to induce higher SPAD values and adequate K, Mg and Mn values according to reference values. Tetra induced the best balanced nutritional values (ΣDOP), especially when compared with Barrier and Cadaman, although it did not differ significantly from GF 677 and Mayor.

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1. Introduction

Peach [*Prunus persica* (L.) Batsch] is the most important temperate and deciduous fruit tree grown in the world, after apples. Spain is the third leading peach producer in the world, only surpassed by China and Italy, and the second larger producer in the EU, after Italy (FAOSTAT, 2014). The main peach producing area is the Ebro Valley, which includes regions of Aragon and Catalonia, and it accounts for 63% of the total Spanish peach production (MAGRAMA, 2014).

Different studies with *Prunus* spp. (Font i Forcada et al., 2012, 2014; Giorgi et al., 2005; Jiménez et al., 2007, 2011; Loreti and Massai, 2006; Moreno et al., 1994, 2001; Remorini et al., 2008; Zarrouk et al., 2005) revealed that the rootstock influences the agronomic performance (tree vigour, yield efficiency, water relations, leaf gas exchange, mineral nutrients uptake, plant size, bloom and harvest dates, and fruit bud survival). The rootstock choice represents one of the most important considerations for a productive peach orchard, particularly in a replant situation (Jiménez et al., 2011; Orazem et al., 2011; Reighard et al., 1997). The use of

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Table 1
List of studied rootstocks, description and origin.

Rootstock	Species	Genetic background	Origin[a]	References
Adafuel	*P. amygdalus* × *P. persica*	'Marcona' seedlings (open-pollinated)	CSIC, Spain	Cambra (1990)
Adarcias	*P. amygdalus* × *P. persica*	Open-pollinated	CSIC, Spain	Moreno and Cambra (1994); Moreno et al. (1994)
Adesoto	*P. insititia*	Open-pollinated	CSIC, Spain	Moreno et al. (1995a)
Barrier	*P. davidiana* × *P. persica*	Open-pollinated	ISF, Italy	De Salvador et al. (2002)
Cadaman	*P. davidiana* × *P. persica*	Controlled cross	INRA (France-Hungary)	Edin and Garcin (1994)
Felinem	*P. amygdalus* × *P. persica*	'Garfi' almond × 'Nemared' peach	CITA, Spain	Felipe (2009)
Garnem	*P. amygdalus* × *P. persica*	'Garfi' almond × 'Nemared' peach	CITA, Spain	Felipe (2009)
Monegro	*P. amygdalus* × *P. persica*	'Garfi' almond × 'Nemared' peach	CITA, Spain	Felipe (2009)
GF 677	*P. amygdalus* × *P. persica*	Open-pollinated	INRA, France	Bernhard and Grasselly (1981)
Mayor	*P. amygdalus* × *P. persica*	Open-pollinated	CIDA, Spain	Cos et al. (2004)
Replantpac	*P. cerasifera* × *P. amygdalus*	Open-pollinated	AI, Spain	Pinochet (2010)
Tetra	*P. domestica*	Open-pollinated	ISF, Italy	Nicotra and Moser (1997)

[a] AI = Agromillora Iberia S.L. private nursery, Spain; CITA = Centro de Investigación y Tecnología Agroalimentaria de Aragón; CIDA = Centro de Investigación y Desarrollo Agroalimentario de Murcia; ISF = Istituto Sperimentale per la Frutticoltura di Roma; CSIC = Consejo Superior de Investigaciones Científicas; INRA = Institut National de la Recherche Agronomique.

rootstocks is mainly directed to overcome soil and disease problems to which scions have limited or no resistance. Peach-almond hybrids (*Prunus amygdalus* × *P. persica*) are largely used as rootstocks for peach trees in the Mediterranean countries. They are tolerant to lime induced iron-chlorosis and alkaline soil conditions, and they are graft-compatible with peach and almond cultivars (Moreno and Cambra, 1994; Moreno et al., 1994; Zarrouk et al., 2005). They are also vigorous and appropriate for use in poor dry soils (Cambra, 1990) and in fruit tree replanting situations (Jiménez et al., 2011; Orazem et al., 2011). In recent years, new selections of peach-almond hybrids have also been developed with resistance to biotic stresses, such as root-knot nematodes (*Meloidogyne* spp.) (Felipe, 2009; Pinochet, 1997, 2009), and tolerance to replant conditions (Jiménez et al., 2011). Similarly, several plum rootstocks used for different stone fruit species have also been released. They adapt well to highly calcareous and heavy-textured soils, being tolerant to root asphyxia and Fe chlorosis and resistant to root-knot nematodes (Moreno et al., 1995a, 1995b).

The present research was carried out over thirteen years of study with 'Big Top' nectarine cultivar budded onto different peach-based diploid rootstocks (almond × peach, peach × *Prunus davidiana*), hexaploid plums and an almond-myrobalan diploid hybrid of different vigour and grown on a heavy and calcareous soil typical of the Mediterranean area, in a replant site. The objective was to evaluate the performance of the rootstocks in these conditions, through tree survival, leaf mineral status, vegetative growth, and yield characteristics.

2. Materials and methods

2.1. Plant material and trial characteristics

Twelve *Prunus* rootstocks, including seven *Prunus amygdalus* × *Prunus Persica* hybrids: Adafuel, Adarcias, Felinem, Garnem, Monegro, GF 677 and Mayor; two *Prunus davidiana* × *P. persica* hybrids: Barrier and Cadaman; one *Prunus insititia* plum: Adesoto; one *Prunus domestica* plum: Tetra; and one *Prunus cerasifera* × *P. amygdalus* hybrid: Replantpac, were evaluated since the third (2003) to the thirteenth (2013) year after planting at the Experimental Station of Aula Dei-CSIC (Zaragoza, Spain) (Table 1). Adafuel (Cambra, 1990), Adarcias (Moreno and Cambra, 1994) and Mayor (Cos et al., 2004) were selected due to their tolerance to iron chlorosis. The hexaploid plum Adesoto was selected due to its resistance to root-knot nematodes and good graft-compatibility with peach (Moreno et al., 1995a). Replantpac (Rootpac® R) shows resistance to root-knot nematodes and exhibits a high tolerance to root asphyxia caused by waterlogging (Pinochet, 2010). Felinem, Garnem and Monegro were selected due to their tolerance to iron chlorosis and resistance to root-knot nematodes (Fernández et al., 1994; Felipe, 2009). GF 677 is the most commonly used peach × almond hybrid rootstock in Mediterranean countries due to its tolerance to lime induced iron-chlorosis and good agronomical performance (Moreno et al., 1994).

These rootstocks were budded with 'Big Top' nectarine cultivar during the summer of 1999, and trees were established in an experimental plot on March 2001. 'Big Top' nectarine is an American cultivar (Zaiger breeding program, USA) highly valued and widespread in the European Union in the last decade (Iglesias, 2010). This nectarine is a mid-season reference cultivar, known for its early coloration resulting in highly colored fruit, sweet taste and optimum fruit size (Della Strada and Fideghelli, 2003; Bellini et al., 2004).

The trial was located in the Ebro Valley (North-Eastern of Spain), on a heavy and calcareous soil, with 28% total calcium carbonate, 8% active lime, water pH 8.4, and a clay-loam texture. Trial was established on a non-fumigated replant site, one year after uprooting an 8-year-old peach ('Summergrand' nectarine cv.) orchard that was budded on plums (*P. insititia*, *P. domestica*) and peach–almond rootstocks. The experiment was established in a randomized block design with five single-tree replications for each scion-rootstock combination. Guard rows were used to preclude edge effects. Trees were planted at 5.5 m × 5.5 m and trained to a low density open-vase system. Cultural management practices, such as fertilization, winter pruning, and spring thinning, were conducted as in a commercial orchard. Open vase trees were pruned to strengthen existing scaffold branches and eliminate vigorous shoots, inside and outside the vase, that would compete with selected scaffolds or shade fruiting wood. Moderate-sized fruiting wood (0.3–0.6 m long) was selected. All trees were hand-thinned at 45–50 days after full bloom (DAFB) leaving approximately 20 cm between fruits. The plot was level-basin irrigated every 12 days during the summer.

2.2. Tree survival and suckering

Tree health and survival were monitored throughout the trial. Dead trees were recorded each year at time when growth measurements were taken. The incidence of rootstock suckering (root and collar suckers) was also recorded during this study.

2.3. Growth measurements and yield characteristics

For all the cropping years, starting in 2003, trunk girth, yield and number of fruits per tree were recorded. Trunk girth was measured each dormant season at 20 cm above the graft union, and the trunk cross-sectional area (TCSA) was then calculated. At harvest, all fruits from each tree were counted and weighted to