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Performance of *Prunus* rootstocks for apricot in Mediterranean conditions

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ABSTRACT

The influence of five rootstocks (Evrica, Krymsk® 86, Torinel, PAC 00-08 and PADAC 01-47) on flowering, fruit set, trunk cross-sectional area, yield efficiency and fruit quality parameters of apricot cultivars (*Prunus armeniaca* L.) grown in a Mediterranean agro-climatic environment was evaluated. The five rootstocks were grafted with 'E-101' and 'E-404' apricot cvs., and established in an experimental orchard in the Region of Murcia (South-eastern of Spain) in 2004. Rootstock had no significant influence on the number of flowers but affected fruit set. Evrica, PAC 00-08 and PADAC 01-47, induced a higher percentage of fruit set on the apricot cultivar 'E-101'. The greatest TCSA was exhibited with Torinel, Evrica and PADAC 01-47. The yield efficiency was significantly greater on PADAC 01-47, because of its higher yield and cumulative production compared with the other rootstocks. Thus, differences in precocity among rootstocks became evident, PADAC 01-47 being the most efficient rootstock for the first bearing years. The fruit quality traits were also significantly affected by rootstocks. In the case of 'E-101', the highest fruit weight was induced by Evrica, Krymsk® 86 and Torinel. In relation to fruit size, the smallest equatorial, suture and polar diameters were produced by fruit on PADAC 01-47 for both cultivars. The highest firmness was induced by PAC 00-08 for 'E-101', while in 'E-404' the highest firmness was induced by PADAC 01-47. The colour of fruit was also affected by the rootstock. The brightest coloured skin (high L^* values) was found on Evrica, PADAC 01-47, Torinel and Krymsk® 86. The fruit weight was positively correlated with pulp yield and negatively correlated with TCSA. According to these results, higher fruit quality was found on PADAC 01-47 and Evrica.

1. Introduction

Apricot (*Prunus armeniaca* L.) is mostly grown in Mediterranean countries, Russia, USA, Iran and Pakistan. Total world production of fresh fruit apricot is approximately 3.1 million tons (FAOSTAT, 2009). In the Mediterranean area, Turkey, Spain, France and Italy are the leading apricot producers and collectively account for 33% of the world's production. According to FAOSTAT, 87,700 tons of apricots were produced in Spain in 2007. The most important apricot-growing area in Spain is the Region of Murcia, followed by the Valencia Community, both located in the South-eastern of Spain. These regions account for approximately 78% of the Spanish apricot production (MARM, 2009). In these areas, but especially in the Region of Murcia, the most limiting edaphic factors are excessively heavy and calcareous soils with a high pH that causes root asphyxia and iron-induced chlorosis (Moreno et al., 2008). In these conditions, the most widely used rootstocks are apricot seedlings ('Real Fino' and 'Canino' cultivars) and plums known as 'Pollizos de Murcia' (*P. insititia*). The seedlings of apricots are still used in some areas, but the tendency is towards their substitution by clonal rootstocks due to lack of tree uniformity and other desirable traits (Moreno, 2009). The apricot seedling rootstocks have good compatibility with all cultivars, but they are very susceptible to *Phytophthora* and *Armillaria*, when grown under irrigated conditions.

The plum rootstocks: Marianna (*P. cerasifera* × *P. munsoniana*), Myrobalan (*P. cerasifera*) and Pollizo (*P. insititia*) have good soil adaptation, but some of them have poor graft compatibility (mainly Marianna and Myrobalans) with those cultivars known as exigent or difficult-to-graft non-congenial cultivars. The *P. insititia* or Pollizos de Murcia has in general good graft compatibility, but problems of excessive suckering are limiting its use (Moreno, 2009).

Rootstocks are responsible for water and nutrient uptake, resistance to soil-borne pathogens and tolerance to environmental stresses (Layne, 1987). Additionally, the most important agricultural attributes of the trees as a biotic unit, such as vigour, productivity, blossom initiation, fruit set, flower set, fruit size and quality, may be strongly influenced by the rootstock (Bielicki et al., 2000; Cinelli and Loreti, 2004; Dichio et al., 2004; Jiménez et al., 2007; Zarrouk et al., 2005).

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A good rootstock should be compatible with scion cultivars, resistant and/or tolerant to pest and diseases, and adapted to a wide range of soil types and climatic conditions (Cinelli and Loreti, 2004; Dichio et al., 2004; Layne, 1987). There are many different types of rootstocks being used for *Prunus* species on a worldwide basis (Rom, 1984). Each one has a particular set of advantages and limitations for adaptation to different geographical regions.

Many studies are available on the agronomic and fruit quality characterization of different apricot cultivars (Akin et al., 2008; Alburquerque et al., 2006; Asma and Ozturk, 2005; Asma et al., 2007; Balta et al., 2007; Drogoudi et al., 2008; Ruiz and Egea, 2008). However, few refer to the agronomic performance of rootstocks for apricots (Egea et al., 2004; Guerriero et al., 2006; Pennone and Abbate, 2006).

The present study was carried out over four years after grafting with two apricot cultivars, grafted on five different rootstocks, and grown on typical heavy and calcareous soil conditions in the South-eastern of Spain. The aim of this study was to assess the influence of these rootstocks on vegetative growth, yield and fruit quality of apricot cultivars.

Fruit set parameters (flower number, flower set, fruit set), plant yield (TCSA, cumulative yield and yield efficiency), physical parameters (fruit and stone weight, flesh firmness, pulp yield, skin colour) and chemical parameters (soluble solids content and acidity) were studied.

2. Materials and methods

2.1. Plant material

Three commercial (Evrica, Krymsk® 86 and Torinel) and two experimental (PAC 00-08 and PADAC 01-47) *Prunus* rootstocks were compared in a trial during a three-year production period: 2006–2008 (Table 1). Rootstocks under evaluation included a plum (*P. domestica*): Torinel, used as the reference rootstock, and four interspecific hybrids.

Evrica is a low vigour plum hybrid and Krymsk® 86 is a high vigour peach–plum hybrid. Both are commercial rootstocks in Russia where they are used for apricots. They have been recently introduced into Spain for field testing. In contrast, the selections PAC 00-08 and PADAC 01-47 are new experimental plum apricot hybrids. The five rootstocks have different levels of tolerance to root asphyxia caused by waterlogging conditions. Also, they are root-knot nematode resistant (*Meloidogyne* spp.) with exception of Kuban® 86 which is susceptible (unpublished).

Rootstocks were grafted with the apricot cultivars 'E-101' and 'E-404'. This choice was due to the possible interest in these two new cultivars in the region of Murcia, because of their maturity time and good fruit quality. All rootstocks showed good anchorage, uniform growth, although they expressed different vigour.

Table 1
Description and origin of *Prunus* rootstocks used in this study.

Rootstock	Species	Origin[a]
Evrica	(*Prunus besseyi* × *P. salicina*) × *P. cerasifera*	Krymsk, Russia
Krymsk® 86	*P. cerasifera* × *P. persica*	Krymsk, Russia
Torinel	*P. domestica*	INRA, France
PAC 00-08	(*P. salicina* × *P. cerasifera*) × *P. armeniaca*	AC, Spain
PADAC 01-47	(*P. besseyi* × *P. armeniaca*) × (*P. cerasifera* × *P. armeniaca*)	AC-EEAD, Spain

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The trial was conducted at an experimental orchard located near Cieza, Murcia, Spain (Latitude 38°17′N–1°27′W). Soil conditions were poor and stony in the first layer (0–10 cm) and clayish below this level (clay-loam texture). Soil was highly calcareous with 15% content of active lime and pH = 8.5. Trial was drip irrigated. Trees were trained to the central leader system and planted at a spacing of 4 m × 2.5 m. Standard cultural practices (pruning, thinning, fertilization and treatments) were performed.

The experiment was established in a randomised block design with five single-tree replications for each scion–stock combination. Guard rows were used to preclude edge effects. Vegetative and fruit quality traits were evaluated over three consecutive years (2006–2008).

2.2. Flowering and fruit set

Flower and fruit set was measured from five trees per rootstock and six branches per tree (30 branches in total per each scion–stock combination). Branches were homogeneous in all cases with a similar length (30–60 cm), located at three different heights in the tree (low–medium–high) and marked at the phenological stage A.

Flower number was counted at the phenological stages D and E (Baggiolini, 1952), flower set at the stage G and the fruit set at the stage I. Periodical controls were carried out every 2–3 days.

Flower set percentage (FSP) was calculated as the number of flower set in relation to the total of flowers in the branch. Fruit set percentage (FS) was calculated as the number of fruit set per total open flowers (Alburquerque et al., 2003). Fruit set was determined five days before harvest time.

2.3. Plant development and plant yield

The following parameters were measured and/or calculated: trunk circumference at 10 cm above the graft union, the total yield (kg $tree^{-1}$) and yield efficiency (kg cm^{-2}). The trunk circumferences were converted into trunk cross-sectional areas (TCSA, cm^2). Cumulative yield per tree and yield efficiency of each scion–stock combination were computed from the harvest data. The plant yield efficiency (kg cm^{-2}) was expressed as the ratio of total cumulative yield in kg per final TCSA.

2.4. Fruit quality parameters

Fruit and stone weight (g) of apricot fruits were determined with a digital balance Sartorius (model BL-600, 0.01 g accuracy) in 40 randomly selected apricot fruits for each scion/stock combination. An electronic digital slide gauge Mitutoyo (model CD-15 DC, England, 0.01 mm accuracy) was used to measure fruit diameters and pulp thickness. Flesh firmness (FF) was determined with a Bertuzzi Penetrometer (model FT-327, Facchini, Alfonsine, Italy) equipped with an 8 mm cylindrical plunger. The measurement was performed on two opposite faces in the equatorial zone (where the skin was removed). Flesh firmness was expressed in kg cm^{-2}. Fruit sphericity was determined as diameter polar/diameter equatorial ratio. Pulp yield percentage was calculated as [(fruit weight − -stone weight)/fruit weight] × 100.

Colour determinations were made in the skin of fruit on four opposite faces in the equatorial zone and the CIELAB L^* (brightness or lightness; 0 = black, 100 = white), a^* ($-a^*$ = greenness, $+a^*$ = redness) and b^* ($-b^*$ = blueness, $+b^*$ = yellowness) colour variables were measured using the chromatometer CR-300 (Minolta, Ramsey, NJ). Besides, the hue angle [$H^{\circ *} = \arctan(b^*/a^*)$] and chroma [$C^* = (a^{*2} + b^{*2})$] were calculated. As suggested by McGuire (1992), hue angle and chroma have been accepted as more intuitively understandable colour variables.