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Rootstock and fruit canopy position affect peach [*Prunus persica* (L.) Batsch] (cv. Rich May) plant productivity and fruit sensorial and nutritional quality

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ABSTRACT

The right combination of rootstock and training system is important for increased yield and fruit sensorial and nutritional homogeneity and quality with peach [*Prunus persica* (L.) Batsch]. We investigated the effects of rootstock and training system on these parameters, testing the effect of vigorous GF677 and weaker Penta* rootstock on 'Rich May' peach cultivar. Fruit position effects regarding photosynthetically active radiation availability, along the canopy profile using the Y training system, were investigated. The positive relationships between total polyphenols content and antioxidant capacity according to canopy vigour and architecture were determined for the two scion/stock combinations. Changes in fruit epicarp colour and content of bioactive compounds were also determined. Lower-vigour trees from Penta* rootstock grafting yielded larger fruit with improved skin overcolour, and greater total polyphenols content and antioxidant capacity. GF677 rootstock produced more vigorous trees with fruit with lower sensorial and nutritional parameters. Canopy position strongly affects fruit sensorial and nutritional qualities. These data define potential for improvements to peach production efficiency and fruit quality, particularly for southern Europe peach cultivation conditions.

1. Introduction

The productivity of peach [*Prunus persica* (L.) Batsch] trees and the sensorial and nutritional quality of their fruit are determined through interactions between different factors. These include rootstock and cultivar interactions, the training system, and more in general, the cultivation techniques adopted under the different environmental conditions. These different factors need to be investigated to increase the production efficiency and fruit quality of this important crop, and consequently its competitiveness in different cultivation environments. Although to a lesser extent than with apple trees (Strong & Miller-Azarenko, 1991), rootstock effects on peach plant development are particularly important, to extend peach adaptation to new training systems that are more adapted to high-intensity cultivation systems. The type of rootstock also affects plant blooming, fruit ripening time, and total fruit production (Carrera & Gomez-Aparasi, 1998), as well as the plant adaptation to specific conditions (Zrig et al., 2011). Furthermore, important effects of rootstock have been seen on peach fruit sensorial parameters, and particularly on fruit nutritional parameters (Giorgi et al., 2005).

The factors that affect the development of grafted trees remain unclear, and are thus continuing objectives of a number of studies. The exchange of endogenous plant hormones between different plant organs is the major mechanism under study, to explain the effects of root/plant interactions on plant productivity and fruit quality (Jackson, 1993).

The reasons for these modifications might be related to the effects of specific root control on plant development, which might also affect the sink rate from the fruit to the shoot. Indeed, it has been shown that dwarf rootstock generally send more nutrients to the fruit because of less competition with the vegetative parts (Chalmers, Mitchell, & Van Heek, 1981).

Among the different rootstock available for peach propagation, GF677 (*P. persica* × *Prunus amygdalus*) is well known for its high adaptability to different types of soil and its induction of high vigour to the resulting peach trees (Giorgi et al., 2005). Due to this behaviour, GF677 is still the major rootstock used for peach propagation, with at least 50% of plants for peach production grafted on

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GF677. This high commercial interest and the particular characteristics of GF677 also means that it is the most used control rootstock in experimental trials to test the effects of new rootstock on peach tree development and fruit quality. However, different international breeding programmes have recently released new *Prunus* rootstock that are considered of interest also for peach cultivation. Among these, Penta* (*Prunus cerasifera*) is indicated as of potential interest for peach propagation, because of its high adaptability to different pedoclimatic conditions, its increased yield efficiency (Nicotra & Moser, 1997), and its reduced vigour, in comparison with GF677.

The yield of well-cultivated trees depends mainly on the total light interception for each part of the canopy structure that is produced by the different training systems (Palmer, 1989; Robinson, Lakso, & Ren, 1991). This important effect arises because the photosynthetic carbon fixation is a function of the sunlight captured by a tree or an orchard. In the intra-tree canopy, the fruit quality changes in response to its architectural position. Indeed, in apple trees (*Malus domestica* Borkh.), fruit on the 1-year-old wood are smaller than fruit that grow on the older wood (Lauri & Trottier, 2004; Volz, Ferguson, Hewett, & Wooley, 1994). Important changes in fruit quality are specifically affected by the uneven distribution of light to the canopy (Tustin, Hirst, & Warrington, 1988) and the light quality; e.g., red light (600–700 nm) increases anthocyanin synthesis in the skin of the fruit (Bastías & Corelli-Grappadelli, 2012).

Excessive vegetative growth can arise from a vigorous rootstock or from an incorrect training system, and can cause canopy shading, which will then reduce the qualitative parametersof the fruit, such as size, colour, sugar content, and secondary metabolite concentrations (Awad, Wagenmakers, & De Jager, 2001; Hampson, Quamme, & Brownlee, 2002; Marini, Sowers, & Marini, 1991; Whiting, Lang, & Ophardt, 2005). However, little is known of the effects of the different types of canopies on fruit nutritional quality. In particular, for new intensive training systems like the Y training system, these can provide benefits towards increased yields, and can reduce the shaded areas of the canopy.

Nowadays, a systemic approach based on the study of the main tree vegetative (trunk area, summer pruning), productive (yield, fruit size) and physiological (photosynthetically active radiation [PAR]) factors, combined with the main fruit sensorial (soluble sugars, °Brix, total acidity) and nutritional (total polyphenols content [TPC] and total antioxidant capacity [TAC]) parameters is seen as an important option. This can provide a better overview of the root/canopy interactions, and consequently of the effects on fruit yield efficiency and nutritional quality.

The evaluation of the nutritional parameters (e.g., TPC, TAC) of different types of fruit is currently an important issue, as fruit nutritional value is of high relevance for the consumer (Abidi, Jiménez, Moreno, & Gogorcena, 2011; Battino et al., 2009; Cantín, Moreno, & Gogorcena, 2009; Giampieri et al., 2012). Several studies have approached the investigation of fruit nutritional value through quantitative methods (Giorgi et al., 2005; Niki, 2011; Re et al., 1999; Scalzo, Politi, Pellegrini, Mezzetti, & Battino,2005), and these have been based on analysis of the fruit TPC, using the Folin–Ciocalteau method (Slinkard & Singleton, 1997), and TAC, mostly using the Trolox equivalent antioxidant capacity (TEAC) or ferric reducing antioxidant power methods. These standard analytical methods have provided high applicability and reliability for a view of fruit quantitative compositional contents of bioactive compounds that are important for consumer health. These methods are now widely applied to screen large breeding populations, with the aim to identify new genetic sources with high bioactive fruit content, as well as to evaluate the effects of specific genetic and cultivation factors on fruit nutritional quality (Capocasa, Scalzo, Mezzetti, & Battino, 2008; Diamanti et al., 2012; Remorini et al., 2008).

The present study was addressed to: (a) compare the effects of vigorous (GF677) and weaker (Penta*) rootstock on peach tree (cv. 'Rich May') vigour and yield, and on fruit sensorial and nutritional quality; (b) to describe the effects of different PAR availability along the canopy profile for the Y training system on fruit sensorial and nutritional quality (fruit position effects); (c) to determine the positive relationship between TPC and TAC changes according to the different canopy vigour and to the architecture observed for the two scion/stock combinations; and (d) to determine the effects of changes in the epicarp colour of the fruit positioned at different levels of the canopy on their content of bioactive compounds.

2. Materials and methods

2.1. Plant material and experimental trial

The peach GF677 (*P. persica* × *P. amygdalus*) and Penta* (*P. cerasifera*) rootstocks were grafted with 'Rich May', a common, yellow pulp, early ripening, peach cultivar. The plants were grafted using micro-propagated rootstock, and planting was carried out during the subsequent winter on a commercial farm of Coop OSAS, Spezzano (CS), Italy, (latitude, 39°43′47.81″ N; longitude, 16°13′52.48″ E), in a sandy soil of pH 8 (sub-alkaline), with medium organic matter (2.43%) and 1.6 g/kg nitrogen content. The orchard was planted with a north–south plant orientation and was managed using the standard integrated pest management system and a stable drip irrigation and fertilisation system.

Considering the different plant vigour, the two rootstock combinations were planted at different plant densities: 1111 plants/ha (4.5 m × 2.0 m) for the more vigorous GF677 rootstock, and 1481 plants/ha (4.5 m × 1.5 m) for the Penta* rootstock. All of the trees were trained according to the 'Y' system. Yearly dormant pruning (December) was combined with summer pruning (May) to form and maintain the 'Y' tree form. For all of the trees, the fruit were thinned in April, depending on the size of the trees and the number of long fruiting shoots that remained after dormant pruning. The data for this study were recorded for the sixth and seventh year after grafting. The trial consisted of a completely randomised scheme of 4 repetitions for each cultivar/rootstock combination (8 plants for GF677, 6 plants for Penta*), which corresponded to a constant fruiting canopy length (12 m).

2.2. Plant development

At the end of each of the two production cycles at six and seven years after grafting, the trunk circumferences were measured at 10 cm above the grafted point. The trunk circumferences were converted into trunk cross-sectional area (TCSA; cm^2).

For both years, the leaf density of the wall canopy was estimated for each plant, using a sampled canopy portion with the following procedure: ten metallic frames 50 cm × 50 cm [0.25 m^2] (five pairs per layer and per repetition) were placed front and back along the profile of the 'Y' slanted wall and distributed randomly. The two frames of each pair were connected with metallic axes to create a regular prism volume. The height of the prism (length of the metallic axes) was equal to the thickness of the slanted wall. Within the perimeter of the prism, the leaves of each shoot were counted. Twenty leaves were randomly selected and detached, and their leaf areas measured using a leaf area metre (Li-Cor 3100, Lincoln, Nebraska, USA). Furthermore, the number of leaves and the leaf area of the canopy in the prism were calculated. This leaf area density (LAD) was converted from 0.25 to 1 m^2 of canopy surface.

The total leaf area per fruiting canopy length (TLA) and the leaf area index (LAI) were determined according to:TLA (total leaf