Xylem manipulation techniques affecting tree vigour in peach and olive trees

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Abstract

Water relations are among the major factors affecting shoot growth and plant vegetative vigor. In many tree crops, dwarfing rootstocks regulate scion vegetative vigor by reducing plant hydraulic conductance. In *Prunus* spp. reduced xylem vessel size leads to reduced hydraulic conductance, but reduction of annual xylem tissue growth could have similar results. The aim of the present work was to investigate the effects of techniques that allow to manipulate xylem tissue growth on tree vegetative vigor. Two different techniques, early trunk girdling and trunk constriction were applied on peach and on olive trees, respectively. In 2010, at the KAC, Parlier, CA, USA, very early girdling (March 31) and late girdling (April 15) were carried out on 8-year-old 'Springcrest'/'Nemaguard' trees. On peach trees, a deciduous species, early girdling (few weeks after sprouting) caused a significant decrease of early season stem water potential and vegetative growth in comparison with trees in which girdling was carried out later in the season and control trees, respectively. On olive trees a plastic strap was applied in December 2008 to cause a trunk constriction limiting trunk growth during the vegetative season. Three-year-old trees of five cultivars grown in super high-density orchard (1600 tree ha^{-1}) near Perugia, Italy, were used for the experiment. Midday stem water potential was lower in constricted trees than in control trees. At the end of the experiment constricted trees had smaller vegetative growth than control trees. Constriction increased yield efficiency, but severe reduction of vegetative growth triggered alternate bearing in the following year. The results of these experiments underline the role of xylem conductance in regulating tree vegetative growth. Techniques aimed at manipulating trunk/branch xylem growth can be effective in reducing tree vegetative growth in tree horticultural species.

Keywords: constriction, girdling, vigour, peach, dwarfing

INTRODUCTION

Tree size and vigour are characters of major importance in horticulture due to their impact on crop management and harvesting cost. The horticultural practice most used to condition tree vigour is grafting on rootstock imparting variable scion vigour according to the rootstock genotype. Rootstock selection and release is a long process that requires several decades to succeed and needs large and long-term funding which is becoming scarcer and scarcer in the last few years.

Identifying potential techniques that can allow regulating tree vigour right in the field, independently of the genetic background of the rootstock/scion combination, could be a very valuable tool for growers. From a physiological point of view, some dwarfing rootstock are able to regulate the scion vigour by reducing the tree stem water potential via reduced hydraulic conductance (Tombesi et al., 2012; Atkinson et al., 2003). Our hypothesis was that it could be possible to simulate the effect of dwarfing rootstock on tree vegetative growth by manipulating trunk xylem growth.

The aim of the present work was to evaluate the possibility of conditioning tree water potential pattern by manipulating xylem. Two experiments, described in Tombesi et al. (2014) and Tombesi and Farinelli (2016), based on scaffold girdling and trunk constriction were considered to evaluate the potential of xylem manipulation to regulate tree vigour.

MATERIALS AND METHODS

Peach girdling experiment

The experiment was conducted in 2010 in an experimental orchard at the University of California Kearney Agricultural Centre, Parlier, CA, USA. Trees used for the experiment were of 'Springcrest' peach grafted on 'Nemaguard' rootstock. All trees were 8 years old, trained to a perpendicular V and received normal horticultural care. Two girdling treatments (removal of a ring of bark with a 6-mm double-bladed girdling knife) were conducted at the base of the two main scaffolds; the first one (early girdling) was conducted on March 31; the second one (late girdling) was conducted on April 15. A randomized block design with five replicates and with single tree plots was used to compare three treatments, namely early girdling, late girdling and an ungirdled control, using 15 trees in all. Midday stem water potential was measured every ~2 weeks on mature leaves that were enclosed in aluminium foiled plastic bags in the morning at least 2 h prior to the measurements. Measurements were made with a pressure chamber (Soilmoisture Corp, Santa Barbara, CA, USA). On June 10 all epicormic shoots on each tree were harvested, weighed and divided into five length classes (0-40, 40-80, 80-120, 120-160 and 160-200 cm).

Olive tree constriction

In December 2008, a constriction (of about 5 cm of height) was applied on the trunk of 5 trees of 5 olive cultivars ('Arbequina', 'Frantoio', 'Leccino' 'Maurino', 'Moraiolo'), using a commercial plastic strap (15×0.6 mm) sealed by means of steel seals (BIR 16 of 16 mm) (Figure 1). It was then removed in December 2009. Time required for strap application was between 1 min tree^{-1} and material cost was less than 0.1 Euro. Trees were 4 years old and they were located in the experimental olive orchard in Deruta (Perugia) (+42°57'38.88" N; +12°25'3.95" E). They were trained as central leader and were planted at 1.5 m spacing along the row, and 4.0 m between rows (1,666 tree ha^{-1}). Another 5 trees per each cultivar of the same age were taken as the control. The orchard was irrigated and all trees received normal horticultural cares. At mid-January 2009, trunk diameter was taken by a calliper (Haglof, Langsele, Sweden) measuring the diameter at the height of the constriction, 5 cm below the constriction and 5 cm above the constriction. The same operation was done in December 2009 and 2010 in order to measure the effect of constriction after tree annual vegetative growth. In the same dates (January 15 and December 1), canopy volume was measured. Tree canopy diameter was measured at four heights: at the base of the canopy, at 50 cm, at 150 cm, and at the top of the canopy. Canopy diameter and height was used to calculate canopy volume as the sum of three truncated pyramids laid one on the top of the other. On October 20, 2009, and October 27, fruits were harvested and weighted for each tree. A sample of about 1 kg was taken per tree. Oil content (Foss-let 1531, Foss electronics, Denmark) and dry weight were measured.

Statistical analysis

Statistical analyses of the data were performed with SAS statistical software (SAS Institute, Cary, NC, USA). Treatments were analyzed by one-way ANOVA with significance level set at 0.05. Means were separated by Tukey's w-procedure at P=0.05. Regressions were performed by Sigmaplot 8.0 (Systat Software Inc., San Jose, CA, USA) and R^2 significance was assessed by ANOVA.

RESULTS AND DISCUSSION

Tree girdling caused a significant reduction of tree vigour as pointed out by the reduction of the number and of the length of water sprouts in peach (Table 1). Early girdling had a larger effect on tree vigour than late girdling. Such results are consistent with the observations reported in many experiments on different tree fruit crops (Weinburger and Cullinan, 1932; Lilleland and Brown, 1936; Crane and Campbell, 1957; Winkler et al., 1974;

Powell and Cash Howell, 1985; Fernandez-Escobar et al., 1987; Agusti et al., 1998; Day and DeJong, 1999). In our experiment early and late girdling caused a significant reduction of mid-day stem water potential in comparison with control (Table 2).

Table 1. Number of water sprouts in peach trees subject to different timing of girdling. Values are means ± SE (n=5).

Water sprout length (cm)	Early girdling	Late girdling	Control
0-40	0.8±0.6	0±0	0.2±0.2
40-80	6.6±0.8	11.2±1.5	5.8±2.3
80-120	12±2.4	12.8±1.2	16±4.0
120-160	4±1.8	3.4±0.2	14.2±2.0
160-200	0±0	0±0	1.2±0.8
Total length of water sprouts	2172±108.6	2428±84.98	4156±290.92

Table 2. Mid-day stem water potential of peach trees subject to different timing of girdling. Values are means ± SE (n=5).

Date	Early girdling	Late girdling	Control
31/03/2010	-0.52±0.02a	-0.6±0.04a	-0.56±0.07a
15/04/2010	-0.78±0.03b	-0.6±0.03a	-0.63±0.03a
03/05/2010	-0.81±0.07c	-0.7±0.05b	-0.55±0.04a
13/05/2010	-0.65±0.03c	-0.6±0.02b	-0.50±0.01a
03/06/2010	-0.56±0.01b	-0.5±0.02a	-0.49±0.02a
10/06/2010	-0.56±0.02c	-0.5±0.01b	-0.48±0.01a

Means with different letters were different per $p<0.05$ (Tukey test).

Water potential reduction was more consistent in early girdled peach trees and the largest water potential reduction occurred right after girdling execution. In late girdled trees water potential followed a similar pattern to early girdled trees, but the magnitude of stem water potential decrease was smaller in comparison with early girdled trees.

In peach, tree vigour regulation by rootstock was associated to the ability of rootstock to decrease midday stem water potential due to xylem anatomical characteristics that cause a reduction of the hydraulic conductance that is correlated with the daily pattern of stem water potential (Basile et al., 2003; Solari et al., 2006; Tombesi et al., 2010). In ring porous species, girdling interrupts the development of early spring xylem in the region of the girdle and results in a period during which xylem water transport cannot keep pace with transpiration and causes decreased midday stem water potentials. In deciduous tree species with ring porous xylem, the outermost part of the xylem tissue is the most conductive and in some species the outermost layer of girth growth accounts for nearly 90% of hydraulic conductance (Ellmore and Ewers, 1985). In peach, spring shoot elongation is dependent on cambium reactivation that leads to the formation of conductive xylem tissue (Améglio et al., 2002). Trunk girdling removes a ring of cambium and disrupts the activity of the cambium as well as retard the formation of new xylem (Noel, 1970). Thus, if girdling is performed in early spring it would coincide with the natural period of maximum girth growth and relative shoot growth. In the present experiment, this was associated with a clear reduction in midday stem water potential. A reduction of shoot growth also occurred shortly after girdling and was likely caused by a decreased hydraulic conductance that resulted in reductions in stem water potential during the healing period subsequent to girdling until new xylem tissue developed and hydraulic conductance capacity was restored (Tombesi et al., 2014).

In olive trees, constriction caused a consistent increase of yield efficiency in the year in which it was applied, but, on the next year, yield efficiency was similar between constricted and control trees (Table 3). In the first year this effect was mainly due to the smaller tree canopy of constricted trees in comparison with control trees whereas yield tree^{-1} was similar across treatments (Table 4). In fact, canopy growth was strongly reduced in constricted trees in comparison with control trees (Table 5).

Table 3. Yield efficiency (kg of oil m^{-3} of canopy volume) in olive trees subject to trunk constriction in 2009. Values are means ± SE (n=5).

	2009		2010	
	Constricted	**Control**	**Constricted**	**Control**
Arbequina	0.48±0.08a	0.31±0.04b	0.13±0.067a	0.157±0.006a
Frantoio	0.32±0.04a	0.18±0.03b	0.07±0.009a	0.021±0.002b
Leccino	0.33±0.02a	0.14±0.01b	0.18±0.017a	0.106±0.011b
Maurino	0.54±0.04a	0.38±0.03b	0.25±0.060a	0.139±0.031b
Moraiolo	0.49±0.11a	0.17±0.01b	0.10±0.035a	0.077±0.010b

Means with different letters were different per $p<0.05$ (Tukey test).

Table 4. Yield (kg of oil tree^{-1}) in olive trees subject to trunk constriction in 2009. Values are means ± SE (n=5).

	2009		2010	
	Constricted	**Control**	**Constricted**	**Control**
Arbequina	0.82±0.07a	0.84±0.07a	0.30±0.12b	1.49±0.09a
Frantoio	0.87±0.07a	0.78±0.23a	0.75±0.07a	0.70±0.13a
Leccino	0.84±0.04a	0.65±0.04b	0.83±0.11b	1.25±0.12a
Maurino	0.64±0.06b	0.92±0.07a	0.52±0.05b	0.93±0.12a
Moraiolo	0.74±0.06a	0.53±0.02b	0.25±0.14b	0.53±0.02a

Means with different letters were different per $p<0.05$ (Tukey test).

Table 5. Two-year canopy volume increase (m^{3} tree^{-1}) in olive trees subject to trunk constriction in 2009 Values are means ± SE (n=5).

	Constricted	**Control**
Arbequina	0.99±0.63b	6.65±0.56a
Frantoio	0.20±0.37b	4.99±0.59a
Leccino	2.09±0.37b	7.12±0.59a
Maurino	0.85±0.41b	4.75±0.90a
Moraiolo	0.41±0.34b	4.78±1.50a

Means with different letters were different per $p<0.05$ (Tukey test).

The reduction of vegetative growth corresponded to lower stem water potential measured in constricted trees (Figure 1). Probably, this was an effect of the reduced xylem girth growth caused by the plastic strap at the constriction point (Tombesi and Farinelli, 2016).

These results point out that a reduction of the xylem growth can have a consistent impact on tree water status and, consequently, have an effect on tree vegetative growth. This suggest that using a simple technique, such the apposition of a plastic strap on the trunk, can allow to regulate the xylem growth and the vegetative growth of the tree. The problem is to understand which is the optimal annual vegetative growth to allow tree size reduction and constant yield efficiency. In fact, in our experiment the annual vegetative growth was so limited that the yield efficiency in the subsequent year was significantly smaller than that in the year of constrictions, meaning that the treatment caused the beginning of an alternate bearing cycle. In fact, new vegetative growth is fundamental for constant bearing over years (Tombesi et al., 2011).

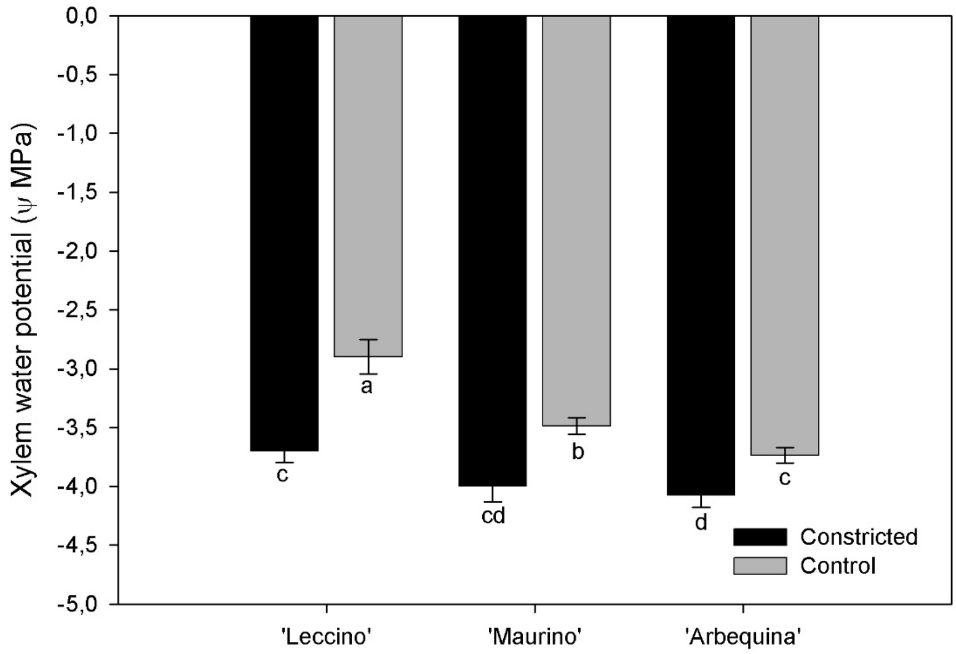

Figure 1. Mid-day stem water potential measured in July 2009 in in olive trees subject to trunk constriction in 2009. Values are means ± SE (n=5). Means with different letters were different per $p<0.05$ (Tukey test).

CONCLUSIONS

Techniques such as trunk girdling and trunk constriction have an impact on water flow through the xylem. Such an effect was quite similar to that of dwarfing rootstock and could be interesting for new researches aimed at understand how to regulate tree vegetative growth by regulating trunk xylem growth. Although trunk constriction applied on olive trees caused the almost complete cessation of vegetative growth, a modulation of this technique (i.e., constriction applied for a shorter time span) could be promising for regulating excessive vigor without the need of grafting on dwarfing rootstocks that in many tree crops are not available.

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