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Does alteration of 'Koroneiki' olive tree architecture by uniconazole affect productivity?

Doron Schneider[a,*], Martin Goldway[a], Reuven Birger[b], Raphael A. Stern[a]

[a] MIGAL, Galilee Technology Center, P.O. Box 831, Kiryat-Shmona 11016, Israel
[b] Agriculture Valley Center, P.O. Box 73, Migdal Haemeq 23100, Israel

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ABSTRACT

High-density olive orchards (1000–3000 trees ha^{-1}) allow use of the continuous straddle harvester that rides over the tree canopy, with very low harvesting and labor costs. However, tree size must be controlled, so that the harvesting machine can pass over the hedgerow and light can penetrate the tree canopy. To achieve this, high-density planted 'Koroneiki' olive trees, aged 5–8 years, were soil-treated with the gibberellin-biosynthesis inhibitor uniconazole at 0.1 or 0.2 g per tree for four consecutive years (2007–2010) to reduce their growth rate. Uniconazole reduced 2007–2010 trunk cross-sectional area increment, 2009–2010 accumulated pruned branch weight, tree height and overall tree size. However, the treatment failed to affect the number of new leaves developed on a shoot, and shoot elongation was not consistently inhibited. Nevertheless, a higher leaf density was found for trees treated with 0.2 g uniconazole per tree starting from the second year of the experiment and newly growing shoots on treated trees exhibited weeping-type growth. As a result, the architecture of the treated trees was changed, with the development of very thick and dense foliage. Cumulative fruit and oil yields for 2007–2010 were reduced in the uniconazole-treated trees, significantly so for the 0.2 g per tree treatment. It was postulated that productivity reduction is a consequence of the altered 'Koroneiki' olive tree architecture, which decreases light interception in the tree canopy. Thus, although the results demonstrate that soil application of uniconazole can be used to control olive tree size in high-density orchards, it should be used carefully to ensure adequate tree illumination, so as to avoid crop loss.

1. Introduction

Olive (*Olea europaea* L.) cultivation has existed in the Mediterranean basin for 5000–6000 years (Connor and Fereres, 2005; Vossen, 2007). Traditional rain-fed olive orchards contain 30–170 trees ha^{-1}. They exhibit relatively low production (1–4.5 t ha^{-1}) with severe alternate bearing, and take 15 or more years to achieve full yield (De la Rosa et al., 2007; Tous et al., 2008; Vossen, 2007). In the last few decades, high production costs, particularly for manual harvesting, have stimulated the redesign of olive orchards. In the 1970s, novel intensively irrigated orchards were established, with 200–800 trees ha^{-1}, suitable for mechanical harvesting with trunk shakers. Those orchards reach full production sooner, and produce higher yields per hectare, but the harvesting costs are still high—up to 35% of total production costs (De la Rosa et al., 2007; Pastor et al., 2007; Tous et al., 1999; Vossen, 2007). At the beginning of the 1990s, high-density (1000–3000 trees ha^{-1}) olive orchards were planted (Tous et al., 2008; Vossen, 2007). This orchard design originated in Spain and is now popular in Europe, America, Australia, South Africa and North Africa (Vossen et al., 2002). The high-density olive production system offers the advantage of early production, but establishment costs are high and long-term production is not known (Vossen, 2007). Labor costs are reduced by more than half and the harvesting operation is shortened because of the high efficiency of the continuous overhead mechanical harvester, which rides over the tree canopy, similar to grape harvesters (De la Rosa et al., 2007; Tous et al., 2008; Vossen, 2007).

The major long-term problem presented by this system lies in controlling tree size, to enable efficient harvesting by the machine and to ensure illumination of the canopy cropping area (De la Rosa et al., 2007). The main strategy used to combat excess vigor is based on selection for low-vigor cultivars. Hence, the olive cultivars Arbequina, Koroneiki, Chiquitita and Arbosana are recommended for planting in high-density orchards (Dag et al., 2006; De la Rosa et al., 2007; Panelli et al., 1994; Rallo et al., 2008; Tous et al., 2008). Dwarfing rootstocks, developed for deciduous species such as apple and pear (Stern and Doron, 2009; Webster, 2001), have not yet been fully developed for olive (Baldoni and Fontanazza, 1990; Pastor et al., 2007; Trifilio et al., 2007). Low irrigation level is another

* Corresponding author. Tel.: +972 4 6953534; fax: +972 4 6944980.
E-mail address: Doronsc@migal.org.il (D. Schneider).

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approach to reducing vegetative growth in olive (Moriana et al., 2003; Palese et al., 2010; Tognetti et al., 2006). For example, Grattan et al. (2006) showed that deficit irrigation in a high-density olive orchard inhibits vegetative growth, but also impairs fruit set and productivity. Irrigation with high-salinity water (Aragues et al., 2010) and low-N fertilization management (Erel et al., 2008) can also control tree vigor, but they reduce productivity as well. Vossen et al. (2002) suggested that application of a growth regulator, to slow growth, might be a means of keeping tree stature to around 3 m, for ease of mechanical harvesting.

The triazoles paclobutrazol and uniconazole are growth regulators that act by inhibiting gibberellin biosynthesis (Rademacher, 2000). Their application inhibits vegetative growth in a wide variety of species (Davis et al., 1988), such as apple (Greene, 1991), pear (Asin et al., 2007; Rai and Bist, 1992), avocado (Wolstenholme et al., 1990) and mango (Kulkarni, 1988; Yeshitela et al., 2004). Therefore, they are commonly used to reduce the need for pruning. In most cases, they also increase productivity through improved flower induction and reduced competition between fruit production and vegetative growth (Meilan, 1997; Rademacher, 2000).

Triazole compounds have been regarded as weak growth retardants of adult olive trees under standard irrigation regimes (Fernandez-Escobar et al., 1992; Lavee and Haskal, 1993; Navarro et al., 1989). Nevertheless, growth inhibition by triazoles has been reported for rooted cuttings of ‘Arbequina’ and ‘Manzanillo’ (Navarro et al., 1989), nursery (1- to 3-year-old) trees of ‘Kalamata’, ‘Manzanillo’ and ‘Leccino’ (Antognozzi and Preziosi, 1986; Wiesman and Lavee, 1994), young (3-year-old) irrigated ‘Muhasan’ trees (Lavee and Haskal, 1993), non-irrigated adult (10-year-old) ‘Maurino’ trees (Proietti and Tombesi, 1996), adult (11-year-old) ‘Kalamata’ trees that had been severely pruned to the scaffold level (Wiesman and Lavee, 1994), and 2- to 5-year-old ‘Barnea’ trees planted at high density (1250 trees ha^{-1}) (Dag et al., 2006). Triazole treatment is inconsistent in its effect on olive productivity: Antognozzi and Preziosi (1986), Dag et al. (2006), Lavee and Haskal (1993) and Avidan et al. (2011) all reported positive effects, whereas Fernandez-Escobar et al. (1992) and Proietti and Tombesi (1996) found no effect.

Our preliminary results showed that soil application of uniconazole can be used to reduce the growth rate of 5- to 6-year-old ‘Koroneiki’ olive trees in a high-density orchard (Schneider et al., 2011). In the present study, we report the results of a 4-year experiment using uniconazole to control tree size in high-density orchards. The effect of uniconazole on ‘Koroneiki’ tree dimensions and architecture was evaluated with particular attention to its influence on productivity.

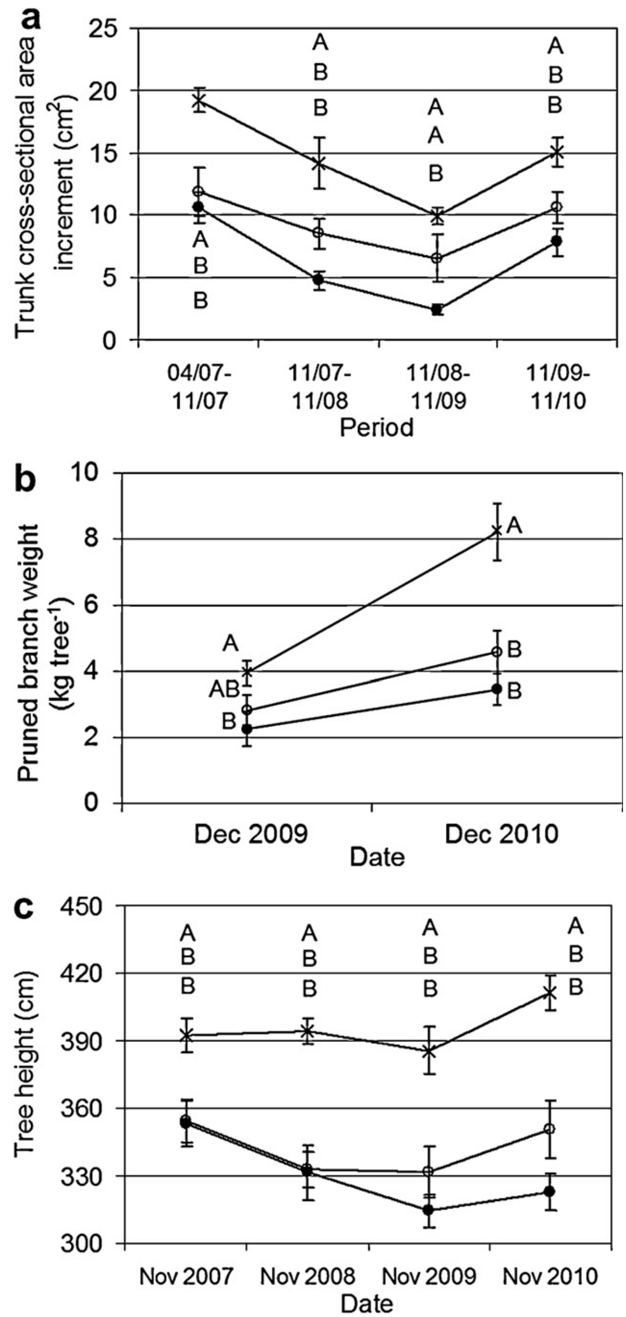

Fig. 1. ‘Koroneiki’ tree trunk cross-sectional area increment (a), pruned branch weight from annual pruning (b) and tree height before harvest (c) in control (×), 0.1 (○) and 0.2 g (●) uniconazole per tree treatments. Means ± SE are presented. Means in the same period or year designated by different letters differ significantly at $P < 0.05$.

2. Materials and methods

2.1. The orchard

The study was conducted in a commercial 10 ha high-density ‘Koroneiki’ olive orchard, planted in 2002 at 1250 trees ha^{-1} with 2 m × 4 m spacing, from 2007 (when the trees were 5 years old) to 2010. The orchard is located in the north of Israel (32.5°N; 35.4°E; alt. 350 m), in a semiarid area with high temperatures (ca. 38 °C max.) and low humidity (<40% RH) during the summer (May–October). Annual precipitation during the winter (November–April) is about 400 mm, with low night temperatures (ca. 2 °C min.) from December to February. The soil is basaltic protogromosol (24% sand, 11% silt and 65% clay with an organic matter content of 1%. Soil pH is 7.1.

The irrigation system consisted of one lateral line per row with 1.6 l h^{-1} pressure-compensated in-line drippers (Netafim, Iftach, Israel) spaced at 0.5 m. The reference annual evapotranspiration rate for the irrigation period (April–November) was about 1300 mm. During this period, the trees were supplied with about 600 mm of water. In 2007, no fertilization was applied to the orchard; between April and August of the years 2008, 2009 and 2010, the trees were fertilized via the irrigation system with N at 30, 30 and 90 kg ha^{-1}, and with K_2O at 40, 50 and 100 kg ha^{-1}, respectively.

2.2. Uniconazole application

The commercial gibberellin biosynthesis inhibitor Magic™ (Sumitomo Chemicals, Hyogo-Ken, Japan), a liquid formulation containing uniconazole at 5% (w/v), was used in all experiments.