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Adopting vigorous olive cultivars to high density hedgerow cultivation by soil applications of uniconazol, a gibberellin synthesis inhibitor

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Abstract

The high-density planting system recently adopted for olive, facilitates the use of efficient over-head mechanical harvesters. To accommodate the harvester only cultivars with restrained vegetative vigor can be used and managed to limit tree size while maintaining high productivity. Spray application of the 0.05% "Magic" (a commercial product containing 50 g L^{-1} uniconazol), or soil application of 2 and 4 g $tree^{-1}$ "Magic", were tested to control the canopy size of fruitful vigorous cultivars to suit the high density hedgerow system and over-head harvesting. Two year old plants were chosen for the initial application. Soil application of 2 g "Magic" (0.1 g $tree^{-1}$ uniconazol) caused a satisfactory balanced growth inhibition of the vigorous cvs. Barnea, Leccino and Picholine to suit the high density hedgerow system. Thus, a significant increase of the choice of cultivars to be used for over-head harvesting could be significantly increased. The use of vigorous cultivars treated with uniconazol for over-head harvesting started in commercial plantations in 2006. In some cases an increase of the annual dosage was required with aging of the trees. This required increase of the annual soil application of uniconazol with aging of the trees needs further observations. An increase in fruit production due to the optimal uniconazol treatment was apparent, though results were rather erratic. Still, production in treated orchards was at least within the country's average for each of the tested cultivars during the experimental years.

Additional key words: gibberellins biosynthesis inhibitor; hedgerow orchard; over-head harvester.

Resumen

Adaptación de variedades vigorosas de olivo al cultivo en seto de alta densidad mediante aplicación al suelo de uniconazol, un inhibidor de la síntesis de giberelinas

El sistema de cultivo en seto de alta densidad, recientemente adoptado para el olivo, facilita el uso eficiente de cosechadoras cabalgadoras mecánicas. Para que la cosechadora pueda trabajar es necesario utilizar cultivares con poco vigor vegetativo manejados de manera que se limite el tamaño del árbol manteniendo alta productividad. Para controlar el tamaño de la copa de cultivares vigorosos a fin de adaptarlos al cultivo en seto con alta densidad de plantación y recolección con cosechadora cabalgadora, se probó la aplicación en pulverización de "Magic" al 0,05% (producto comercial que contiene 50 g L^{-1} de uniconazol), o la aplicación al suelo de 2 y 4 g de "Magic" por árbol, utilizando plantas de dos años para la aplicación inicial. La aplicación al suelo de 2 g de "Magic" (0,1 g uniconazol por árbol) en tres cvs vigorosos, Barnea, Leccino y Picholine, provocó una inhibición de crecimiento satisfactoria y equilibrada. Por tanto, esta técnica puede proporcionar un mayor número de cultivares adaptados a la recolección mecánica con cosechadoras cabalgadoras. El uso de cultivares vigorosos tratados con uniconazol para recolección con cosechadora mecánica se inició en 2006 en plantaciones comerciales. En algunos casos fue necesario un aumento de la dosis anual en plantaciones de mayor edad, aunque son necesarias más observaciones. Aunque fue evidente un aumento en

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la producción de fruto debido al tratamiento óptimo con uniconazol, los resultados fueron bastante irregulares. Sin embargo, la producción en las plantaciones tratadas estuvo al menos dentro de la media del país para cada uno de los cultivares evaluados durante los años de experimentación.

Palabras clave adicionales: cosechadora cabalgadora; inhibidor de la biosíntesis de giberelinas; plantación en seto.

Introduction

Presently an intensive high density hedgerow growing system is developing for the future olive (*Olea europaea* L.) industry and is being studied world-wide (Tous *et al*., 1999; Dag *et al*., 2006; De la Rosa *et al*., 2007). This relatively new olive growing system is based on planting distances of 1.2-2.5 × 4 m producing a hedgerow canopy kept at a diameter of 1.5 m and a height of 2.5-3.0 m. These orchards are harvested with an over-head harvester found considerable more efficient than the trunk and scaffold shakers used in the more spaced conventional rain fed or intensive orchards (Tous *et al*., 1999; Lavee, 2006, 2010; Pastor *et al*., 2007; Vossen, 2007). The increase of tree number per hectare enabled harvesting a commercial yield already 3 years after planting (Dag *et al*., 2006; De la Rosa *et al*., 2007). Furthermore the use of the over-head harvesters in these orchards reduces the harvest cost by 65% compared to shaker harvesting in standard spaced parallel intensive orchards.

Still, the main limiting factor with this system is the width and height of the trees to suit the harvester. Heavy pruning is required for most standard cultivars to control canopy size and tree architecture. The removal of many newly developed shoots to control the hedge size decreases the potential yield while the remaining branches tend to thicken more rapidly and limit the efficient use of the over-head harvesters (Dag *et al*., 2006; Tous *et al*., 2008). Thus, the overall long term production of the high density hedgerow orchards is generally not higher than the production in parallel more spaced shaker harvested intensive orchards. Still, the hedgerow growing system is rapidly spreading in spite of the higher establishment cost. This is mainly due to the somewhat higher production during the first two years and in the marked reduction in the harvest cost. Rather few traditional cultivars are suitable for this system such as Arbequina, Arbosana, and Koroneiki, characterized by their compact growth and medium-low vigor requiring only moderate pruning when grown in the hedgerow system (Lavee *et al*., 2003; Pastor *et al*., 2007; Rallo and De la Rosa, 2007; Tous *et al*., 2008). Only very few new cultivars such as FS-17 (Fontanazza *et al*., 1998), Askal (Lavee *et al*., 2003), Chiquitita (Rallo *et al*., 2008) and Arbosana have been developed to present and commercially released specifically for the dense hedgerow orchard. Even these cultivars aimed to broaden the diversity of cultivars for this type of orchard are mostly still under observation for their performance. Controlling the tree size to increase harvest efficiency and ensure light penetration for high productivity remains a limiting factor for the high density hedgerow olive orchards (De la Rosa *et al*., 2007). Plant Growth Regulators (PGR), such as gibberellin biosynthesis inhibitors are good candidates to help regulating tree growth and fruit production (Vossen *et al*., 2002).

Application of triazols (paclobutrazol and uniconazol) inhibited vegetative growth in a wide range of species such as mango (*Mangifera indica* L.) (Kulkarni, 1988; Yeshitela *et al*., 2004), avocado (*Persea americana* Mill.) (Wolstenholme *et al*., 1990), apple (*Malus* × *domestica* (Greene, 1991), and pear (*Pyrus* sp.) (Rai and Bist, 1992; Asin *et al*., 2007). Application of triazols (paclobutrazol) to irrigated, large, adult olive trees of cvs. Manzanillo and Barnea had no dramatic effect on the vegetative growth but significantly increased productivity (Navarro *et al*., 1989; Lavee and Haskal, 1993). On the other hand, growth inhibition has been reported for young 1-3 year old olive trees of cvs. Kalamata, Manzanillo, Muhasan and Leccino (Antognozzi and Preziosi, 1986; Lavee and Haskal, 1993; Weisman and Lavee, 1994). Similar results were reported for irrigated young Barnea olive trees planted in high-density (1,250 trees ha^{-1}) hedgerow plantation (Dag *et al*., 2006). Thus, the possibility of controlling the growth of vigorous cultivars to perform in the hedgerow system would widen considerably the choice of cultivars to be used in this harvest efficient dense orchard system.

In this study the effect of uniconazol (applied as the commercial product Magic), on the vegetative and re-

Abbreviations used: PGR (plant growth regulator).

productive performance of vigorous fruitful olive cultivars grown under high-density hedgerow conditions was determined. The study was conducted both in an experimental plot planted specially for this purpose in the Galilee experimental farm Kfar-Hanania and in two large scale commercial orchards at Kibbutz Magal in the eastern edge of the central coastal plain and in Kibbutz Gshur at southern Golan Heights. The experimental results of the three regional plots are presented and discussed.

Material and methods

Experimental plot

The study was conducted in a high density drip irrigated olive orchard (2 × 4 m) of various cultivars that were planted in April 2000 in the lower Galilee Mountains at the Kfar Hanania experimental farm (north Israel). The trees were trained to a central leader and after 2 years reached a height of about 2.5 m and filled the in-row spacing. Four rows of the cv. Barnea were selected in February 2002 for the study. The gibberellin synthesis inhibitor used was uniconazol using the commercial product "Magic" (Magic contains 50 g L^{-1} active ingredient, produced by Agan Chemicals Israel). On March 7, 2002 four treatments were applied in 4 replicates of 6 trees in randomized blocks (24 trees per treatment): (1) control (untreated trees), (2) spray application of 0.05% Magic, (3) soil application of 2 g Magic $tree^{-1}$ [0.1 g uniconazol], and (4) soil applicatioof 4 g Magic $tree^{-1}$ (0.2 g uniconazol). Soil application treatments were performed by applying the desired volume of a 20% stock solution of uniconazol under 3 drippers for each treated tree. For canopy application of uniconazol a hand gun sprayer was used, applying about 3 L spray solution $tree^{-1}$ to reach full coverage (equivalent to 0.75 g uniconazol). The surfactant Triton X-100 at a rate of 0.05% was added to the spray solution. Trunk circumferences (cm), tree height (m) were recorded in the winter of each year after harvest before pruning. Yield (kg $tree^{-1}$), fruit size (g), and maturation index were also determined annually. The rate of fruit set was measured in July 2003 using 80 pre-tagged branches per treatment with 100 inflorescences on each. Pruned branches were weighted separately for each replicate. The presented results presented are averages of the four replicates. The 2X standard errors (SE) were calculated and represented for each measured criteria.

Commercial plots

Cultivar performance was followed in two high density hedgerow system orchards, one in Kibbutz Magal (at the eastern edge of the coastal plain in the central part of Israel), and the second in Kibbutz Gshur (at the southern region of the Golan Heights, north-east of Israel). In kibbutz Magal, uniconazol was applied via the irrigation system to a 6 ha commercial plot of cvs. Barnea and Leccino. The orchard was planted in 2003 at spacing of 4 m between rows and three different in-row distances, 2, 2.5 and 3 m, between trees. The trees were trained to a central leader. The total planted area of each tested density and cultivar was one hectare divided in two parallel blocks with four rows each. The rows with the different densities were distributed randomly in each of those blocks. Soil application of 3 g Magic $tree^{-1}$ (0.15 g uniconazol) introduced through the irrigation system in February 2006 followed with two additional doses, each of 2 g Magic $tree^{-1}$ in April 2006, and in July 2007. Harvesting was performed using a broad New Holland over-head grape harvester adjusted for olive hedgerow harvesting. Harvest time was performed in accordance with the commercial maturation stage for each cultivar and year. The harvested fruit was weight separately for each treatment every year. Both harvester efficiency and yield in the three in-row planting distances were compared. Samples of 1 kg fruit from each repetition and treatment were taken to the laboratory for fruit size (g), maturation index (Boskou, 1996 and oil content (Avidan *et al*., 1997) determination.

In Kibbutz Gshur, a 50-ha high density hedgerow orchard composed of several cultivars was planted in 2002 at distances of 2 × 4 m and trained to a central leader shape. In this plot, one hectare of each of the cultivars Barnea, Picholine, Leccino, Arbequina, Koroneiki and Souri were exposed to uniconazol (Magic) soil application. The starting year and the doses applied each year varied for each cultivar in accordance with its vigor and performance (Table 1). The harvest was performed using the same Broad New Holland over-head harvester as in Kibbutz Magal. Yield data and harvesting efficiency for each of the cultivars were determined annually starting from the 2006 season, the second year of commercial cropping in that orchard. The yield and harvesting efficiency of some of the cultivars in that orchard were compared to the mean performance of those cultivars in intensive regularly spaced shaker harvested orchards in the region.

Table 1. Yield of three vigorous cultivars (kg tree^{-1}) in a commercial high density hedgerow orchard planted in 2003 at Kibbutz Gshur in the north of Israel and treated annually with uniconazol (Magic) three years after planting. After the yield of 2007 the level of Magic applied was increased from 2 to 3 g tree^{-1} for one year

Cultivar	Magic application (g tree^{-1})	Years after planting				
		3 (2005)	4 (2006)	5 (2007)	6 (2008)	7 (2009)
Barnea	0	5.96	*13.71*	*14.52*	*8.11*	*6.42*
	2		12.03	16.92		
	3				10.05	10.13
Picholine	0	7.54	9.15	*6.23*	*9.71*	*14.11*
	2			19.91		
	3				6.57	16.12
Leccino	0	6.67	10.48	*9.38*	*6.33*	*0.5*
	2			16.41		7.57
	3				9.39	

The control figures in italics refer to the average yield of regular spaced intensive orchards of those cultivars in Israel.

In 2008 oil samples extracted from fruits of each of all six cultivars (cvs. Barnea, Leccino, Picholine, Arbequina, Koroneiki, and Souri) treated with uniconazol (Magic) were sent for residue analysis to the specialized residue laboratory of the Volcani Center in Bet-Dagan.

Results

Experimental plot

The effect of uniconazol on trunk circumferences of the cv. Barnea trees was measured in March 2003 one year after the application (Fig. 1a). A marked reduction in the circumference of the trunk was noticed mainly in the high dose (4 g Magic) soil treated trees. The trunk circumference of both the sprayed and the 2 g soil treatments were not affected significantly. Though, a tendency of reduction was apparent in comparison to the untreated control trees. This reduction was the smallest on trees in the spray treatment. The tree height at the end of each growing season was significantly inhibited in the two soil treatments, while the sprayed trees were not affected (Fig. 1b). The small non significant retardant of the trunk circumference due to the 2 g tree^{-1} Magic soil treatment after the first year was not noticeable in the following years, although the trees were exposed to Magic annually (Fig. 2). The rate (%) of fruit set on the tagged branches, determined in July 2003 three months after flowering, increased slightly over the control (non-significant) on the trees subjected to the lower uniconazol (2 g Magic) concentration applied to the soil. However, this small increase in fruit set was followed by a significant increase of about 50% in yield (Fig. 3). This increase in yield could be related to the marked reduction of the annual pruned fruiting shoots followed by the inhibition of the tree's height (Fig. 4). The relative small non significant yield increase in the 4 g tree^{-1} Magic soil treated trees was apparently the result of over suppressed annual shoot growth decreasing the canopy volume. Both the 4 g Magic soil application treatment, with a too drastic impact on tree development, and the 0.05% Magic

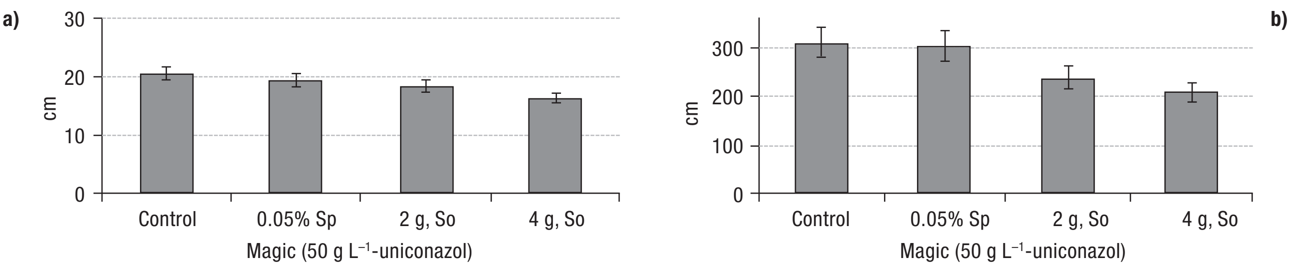

Figure 1. Trunk circumferences (a) and tree height (b) of cv. Barnea olive trees grown in the experimental plot at Kfar Hanania one year after exposure to different doses and application methods of Magic. Vertical bars = 2 × SE; planting, April 2000; application of treatments, April 2002; measurements, January 2003 before pruning. Sp: spray application. So: soil application.

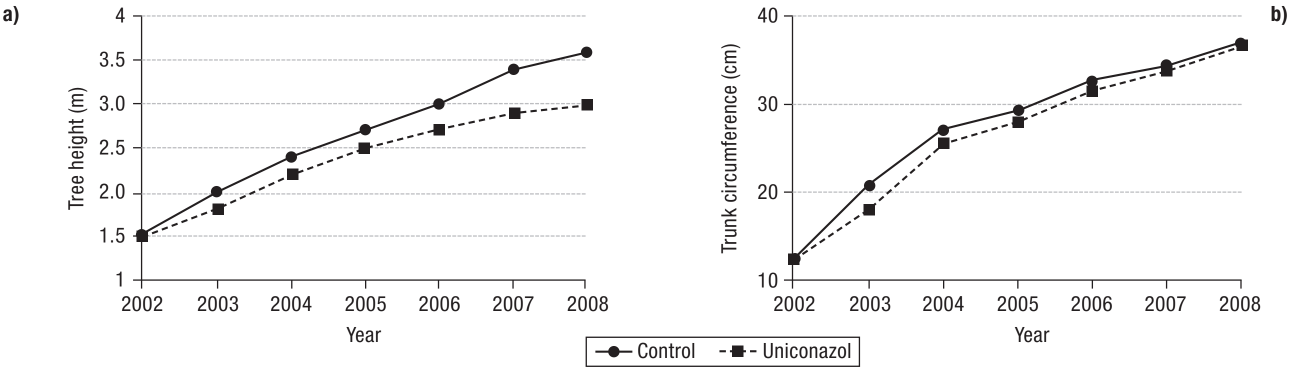

Figure 2. Increase in a) tree height and b) trunk circumference of young cv. Barnea trees grown in the experimental plot at Kfar Hanania during six years of annual treatments with uniconazol (2 g Magic tree^{-1}) and the comparable untreated control trees.

spray treatment with no impact on tree growth, were abandoned after the first two seasons. On the other hand, the study continued with the trees receiving the 2 g tree^{-1} Magic (0.1 g uniconazol) as soil application and the control-untreated ones for additional 4 years. In the 4th spring (March 2006) the application of Magic was increased from 2 to 3 g tree^{-1} due to the increase in the tree size and age. Comparing the growth of Magic treated and control trees over a period of six years (2003-2008) revealed a reduction of about 16.5% in tree height (3 and 3.6 ± 0.2 m, respectively). The reduction in tree height was accompanied by a marked change of the tree's growth habit. Long droopy shoots developed on the treated trees (Fig. 5) in contrast to the natural upright growth habit of the cv. Barnea and the other upright cultivars in the commercial treated plots. These droopy shoots although long and thin were highly fruitful and the resulting hedgerow was most suitable for over-head harvesting (Fig. 6). The soil applied uniconazol increased the yield of cv. Barnea trees in 4 out of 6 recorded years (Fig. 7). The cumulative yield during that period increased from 17 kg tree^{-1} in the control to 27.5 kg tree^{-1} in the uniconazol (Magic) soil treated plots. The total production during the first six fruiting years of the treated trees increased by more than 60% over the untreated control trees. No direct effect of the uniconazol treatments on fruit size, rate of maturation and the oil content in the fruit were found (thus data not shown). All fruit characters were strictly related only to the level of fruit load on each tree as common for olive trees in general.

Commercial plots

Plots of cvs Barnea and Leccino with different in-row tree spacing located in Kibbutz Magal were treated

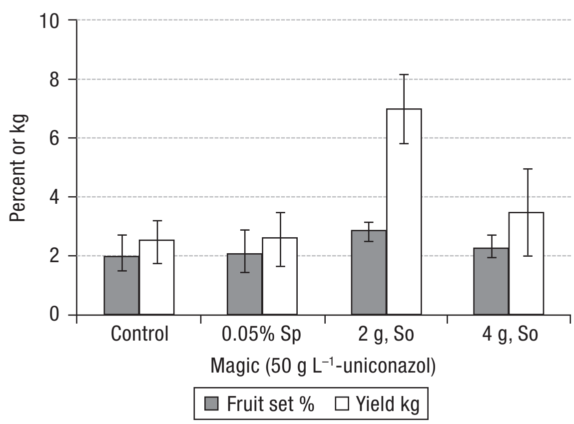

Figure 3. Percentage of fruit-set (July 2003) and yield (kg tree^{-1}) at harvest (November 2003) of cv. Barnea olive trees grown in the experimental plot at Kfar Hanania exposed to different doses and application methods of Magic in April 2002, two years after planting. Vertical bars = 2 × SE. Sp: spray application. So: soil application.

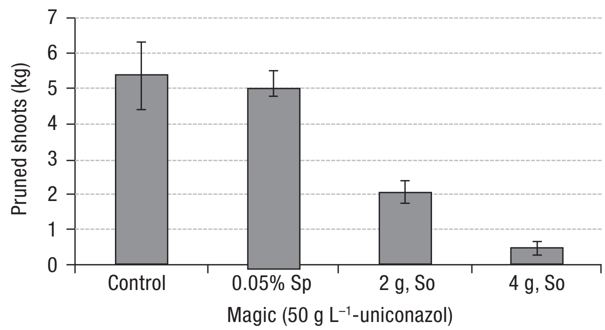

Figure 4. Weight of pruned branches (kg tree^{-1} in December 2003) of three year old cv. Barnea trees grown in the experimental plot at Kfar Hanania exposed to different doses and application methods of Magic in April 2003 two years after planting. Vertical bars = 2 × SE. Sp: spray application. So: soil application.

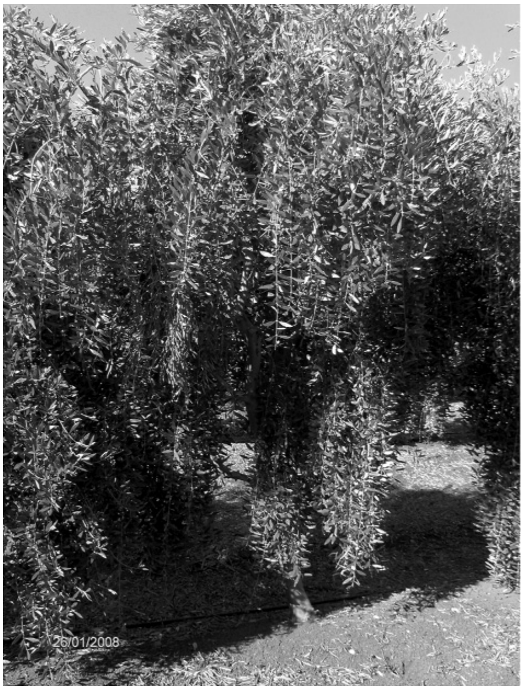

Figure 5. A five year old cv. Barnea tree in a commercial plot at Kibbutz Magal with droopy lateral branches after two years of soil applications of 2 g Magic in March of each year.

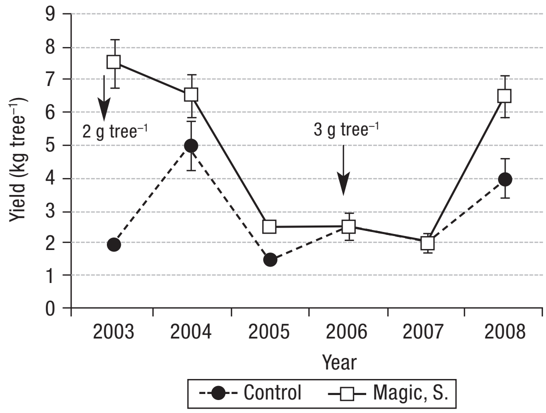

Figure 7. Effect of Magic on the yield of cv. Barnea trees grown in the experimental olive plot at Kfar Hanania, over a period of six years (2003-2008) of exposure to soil application of uniconazol (2 g Magic tree^{-1} annually applied in March till 2005; since 2006 the amount was raised to 3 g in the following years).

with uniconazol. The two cultivars Barnea and Leccino responded to the uniconazol treatments somewhat differently, in accordance with the in-row tree spacing and the crop year (Figs. 8 and 9). In cv. Leccino, which was strongly alternating with an extreme "off" year in 2007, tree spacing in the row had only a minor effect on fruit production during the three years recorded. In cv. Barnea, on the other hand, which was only slightly alternating, the narrower tree spacing of 2 m produced in two out of three years a higher crop than the trees in the two wider spaced rows. In 2007 (the off year of cv. Leccino), the cv. Barnea had a relative good crop with the highest yield at the 2.5 m row spacing. In both cultivars the trees in the 3 m spaced rows in that young orchard had annually a somewhat lower yield in comparison with those in the two denser spaced rows.

The accumulated yield for the three successive years (2006, 2007 and 2008) revealed a clear different response to spacing in the rows of the two cultivars. In cv. Leccino the cumulative yield of the two in-row denser planted trees was about the same and significantly higher than in the rows with 3 m spacing between the trees (Fig. 9). In cv. Barnea however, only the 2 m in-row tree spacing produced a higher yield while the yield of trees at 2.5 and 3 m spacing was about the same and significantly lower than in the dense rows. It should be noted that a continuous increase in yield during the three years was found only with cv. Barnea planted at the 2 m spacing (Fig. 8). The harvesting efficiency of the over-head harvester, on per area basis, was about the same in all plots. No significant differences were found either between the two cultivars or the three different in-row density plantings. The overall harvest ability was of about 4 ha per working day, 2.5-3 times more rapid than shaker harvesting in parallel intensive standard spaced orchards with about the same yield.

The oil content (% of fresh weight) was determined annually in samples from each plot. No significant

Figure 6. A densely planted hedgerow of cv. Barnea trees treated with uniconazol showing controlled height and droopy lateral shoots suitable for efficient over-head harvesting in the commercial olive orchard of Kibbutz Magal.

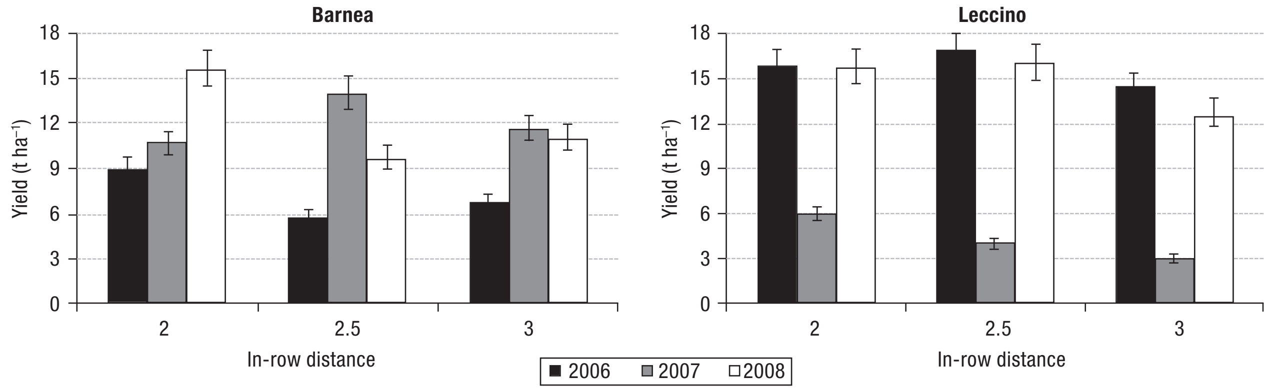

Figure 8. Annual yield of cvs. Barnea and Leccino trees planted at three different in-row spacing in a commercial olive orchard at Kibutz Magal. The orchard was treated with uniconazol via the drip irrigation system with 3 g Magic tree^{-1} in February and 2 g tree^{-1} in April 2006, and with 2 g tree^{-1} in July 2007.

differences in the oil content of the fruit harvested from the trees grown at different in-row spacing was found in either of the two cultivars in any of the three monitored years. The oil content in the fruit of the cv. Barnea was each year higher (20-22%) than the oil in the fruit of cv. Leccino (16-18%). Fruit size and maturation time was also not effect by the uniconazol as such but were related to the individual fruit load similarly on treated and control trees.

In the commercial high density hedgerow plot at Kibbutz Gshur composed of a number of different cultivars the first harvest was in 2005, three years after orchard establishment. The fruit of each cultivar was harvested separately using an over-head harvester. Less vigorous cultivars such as Arbequina, Koroneiki and Souri required no pre-pruning of the trees to fit the over-head harvester. On the other hand the vigorous cv. Barnea trees reached a height of more than 3.5 m and a width of 2 m. Almost all the branches above the height of 2.7 m and the width of 1.5 m were removed before harvest. The fruit on those removed branches was collected manually and amounted to a quantity of 5 t ha^{-1}. After this first yield a soil application of 2 g Magic tree^{-1} was applied to this cultivar in March 2006. The annual shoot growth of the treated cv. Barnea trees during the 2006 season was reduced by about 40-50%. The average length of the top shoot on the treated trees was not more than 60 cm while that of untreated trees in the neighboring standard plots of the same age was 100 cm and more. No pre-pruning was required on the treated trees before harvesting with an over-head harvester in November 2006 which removed more than 90% of the total fruit. On basis of these results, a 2 g Magic tree^{-1} soil treatment was applied again to the cv. Barnea trees in April 2007 as well as to the trees of the cvs. Picholine and Leccino. The trees of both these cultivars in the dense hedgerow system also responded well to the growth retardant and were successfully harvested

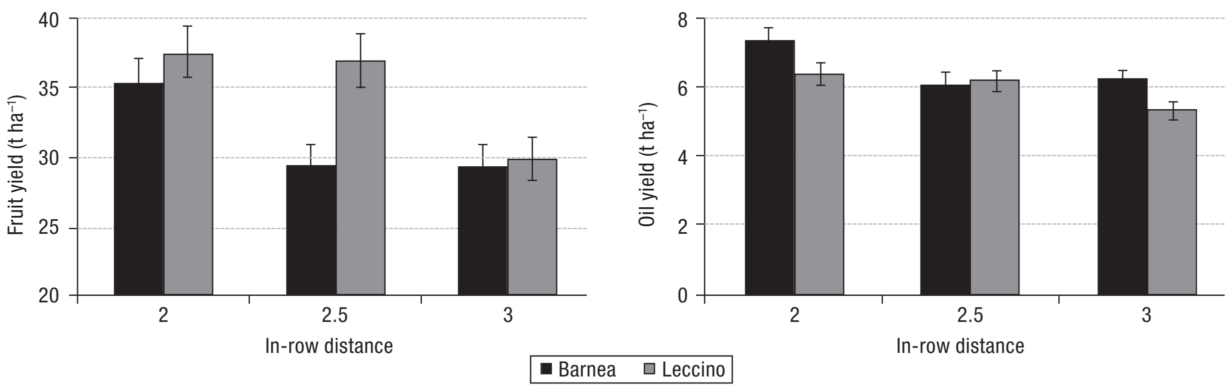

Figure 9. Cumulative fruit and oil yields of hedge row planted cvs. Barnea and Leccino in a commercial olive orchard at Kibutz Magal treated in the years 2006-2008 with uniconazol, at each of three in-row spacing distances of 2.0, 2.5 and 3.0 m. Treatments as described in Figure 8.

in the autumn of 2007 with the over-head harvester without requiring any pre-harvest pruning. The yield in these plots was relatively higher in most cases but remaining in the same order of magnitude of the average yield of these cultivars in spaced intensive orchards in the country (Table 1). In the following year (2008) 3 g Magic tree^{-1} was applied in April via the irrigation system to all three cultivars. The yield in the following autumn was relatively low following the high yield in the previous year. However, in spite of the "off" year with generally enhanced vegetative growth, the annual shoots growth of the trees in the treated plots remained controlled. As in the other plots, the annual shoots revealed a droopy nature and no pre-pruning for the over-head harvester was required. Harvesting in these plots with the over-head harvester was as in Kibbutz Magal about 3X more efficient than shaker harvesting in the intensive standard spaced neighboring orchards. Also as in the other locations fruit size, rate of maturation and the fruit's oil content were affected only by the level of fruit load regardless if the tree was treated with uniconazol or not. The 3 g Magic tree^{-1} application in the spring of 2008 introduced via the irrigation system, included for the first time also plots of the weaker growing cvs. Arbequina, Koroneiki and Souri. In spite of the increased concentration the effect of uniconazol on the naturally restrained growth of these cultivars was negligible and no effect on the yield and fruit characteristics was found during the harvest in the following autumn of 2008 (data not shown). Samples of oil extracted from the fruits of the treated trees of all six cultivars were sent to the analytical residue laboratory of the Volcani Center for uniconazol and its degradation compounds analysis during December 2008. No uniconazol residues or specific degradation compounds were found in any of the oil samples extracted from the fruit grown on uniconazol treated trees.

Discussion

Spray application of a commercial preparation of 0.05% Magic at a rate of 3 L tree^{-1} or 0.075 g uniconazol tree^{-1} was nearly ineffective neither on vegetative growth nor on the fruiting potential of cv. Barnea trees. This is in agreement with previous studies on the effect of various triazol gibberellin synthesis inhibitors with olives (Lavee and Haskal, 1993) and other fruit trees (Kulkarni, 1988; Greene, 1991; Asin *et al*., 2007). On the other hand a 2 g Magic (0.1 g uniconazol) soil application tree^{-1} caused a clear inhibition in tree height, changed the growth habit of the seasonal shoots and the fruiting potential.

Effects of gibberellin biosynthesis inhibitors and other vegetative growth retardants, on yield increase through better differentiation, higher fruit set or increase in mean fruit size were previously documented in many fruit species (Kulkarni, 1988; Wolstenholme *et al*., 1990; Greene, 1991; Rai and Bist, 1992; Yeshitela *et al*., 2004) and in olive (Antognozzi *et al*., 1989; Lavee and Haskal, 1993). In olive, gibberellins are the main growth regulators which affect vegetative growth. Auxins and cytokinins are also part of the basic developmental metabolism of the olive as was demonstrated many years ago in olive tissue culture systems (Lavee and Messer, 1969; Rugini, l988). Auxins were also found to be the major agent effective in chemical spray thinning of olives. However, exogenous application of auxin to olive shoots has no effect on their growth but for application at extreme toxic concentrations. Gibberellins on the other hand have a major effect on olive shoot growth though its uptake by external application is rather limited. In our experimental plot, both vegetative growth inhibition and fruiting enhancement of the young trees were clearly demonstrated due to soil application of 2 g Magic tree^{-1}. Soil treatments with higher concentrations of uniconazol inhibited strongly the vegetative growth of young olive trees to a level of reducing the fruiting potential of trees. It seems however, that the optimal growth and fruiting control of older vigorous trees for the hedgerow system might require in some cases higher uniconazol concentrations. The change of the growth habit of vigorous upright cultivars due to uniconazol to a droopy willowy one enables to enlarge the scope of cultivars suitable for the hedgerow cultivation system. The potential yield of these cultivars although satisfactory does not exceed that of spaced irrigated orchards with more vigorous cultivars. Although harvesting hedgerows with over-head harvesters is more efficient than the use of shakers some of that advantage gets lost by the higher establishing and sometimes maintenance costs. The development of new more efficient cultivars for the high density hedgerow growing system is in progress but it is a long process which could bare satisfactory results only gradually. The uniconazol-induced change of the growth habit of vigorous highly fruitful cultivars to fit the use of over-head harvesters might presently increased the fruit production and thus, be instrumental in elevating the fruiting potential of the hedgerow system. The willowy type of the annual growth although long and thin is highly productive and suitable for an efficient use of harvesters. A reduction in tree size of the vigorous cultivars could be achieved also by limiting nutrition and irrigation schedules. However, deficit irrigation does not change the growth habit of the trees and when effective in reducing tree size causes in most cases also a reduction in yield potential. The exposure of even the most vigorous cv. Barnea trees, to uniconazol casing the development of long willowy fruitful shoots and led to reduced tree height without reducing its fruiting potential. This trend was most pronounced when planted at 2 m in-row tree spacing. The yield of cv. Leccino grown under the same conditions was highly biannual and not affected by the in-row planting distances. Generally, the yield of both cultivars under the growth inhibited conditions was relatively high and at least in the range of these cultivars in untreated spaced intensive orchards. An accurate comparison of the production of these cultivars with untreated trees under the same growing conditions and spacing in the commercial orchards was not available. Thus, the annual production was compared to the average yields of these cultivars in the country. This comparison, although somewhat erratic, assures at least no production problems due to the uniconazol treatment.

It should be noted that the trunk circumference of uniconazol treated trees was slightly inhibited during the first and second years after the initial treatment. This effect however, was temporary as after six years of uniconazol applications the trunk circumference was the same as in the pruned untreated controls. The similar cambial development in the treated and control trees is probably due to the massive droopy growth compensating for the inhibited upright elongation one.

The time and dose for the initial application of uniconazol to vigorous cultivars planted in the hedgerow system, is dependent and should be applied in accordance with tree vigor. The actual tree vigor to be considered should be based on the interaction between the cultivar and the environmental conditions at the orchard's site. This is critical both for developing the right tree size without losing the initial yield and avoiding the need of pre-pruning before operating the over-head harvester. The growth inhibiting affect of soil applied uniconazol on young cv. Barnea trees is rapid and effective already within the season of application. A soil treatment of 2 g Magic tree^{-1} in March transformed the vigorous growth induced by the strong post-harvest pruning of the previous year to a moderate fruitful droopy growth suitable without further preparation for over-head harvesting. A similar application of Magic in the following spring kept the trees in a controlled size yielding again a high crop harvested efficiently by an over-head harvester. Applying uniconazol to three cultivars with naturally restrained growth had no significant effect on either tree size or level of fruiting. Thus, the policy of choosing the suitable Magic treatments for cultivars to be planted in the hedgerow system will depend heavily on the growth nature and vigor of the cultivars involved.

It became clear from the present study that vigorous fruitful and efficient cultivars can be adopted by means of uniconazol treatments to fit the high density hedgerow system. This growing system would greatly benefit from a wider range of cultivars with high fruiting potential and a diverse organoleptic range. Both cvs. Picholine and Leccino were tested in addition to the cv. Barnea for their response to uniconazol and are already used on a limited scale together with the cv. Barnea in some small scale commercial hedgerow establishments.

The rate of harvest and its high cost makes the dense hedgerow system highly attractive for the future olive industry. Still, the long term yields achieved to present in hedgerow orchards are not acceding those of the more spaced intensive plantations except during the first two crop years. The breeding of new varieties with a high long term fruiting capacity and moderate vigor suitable for the hedgerow system, although in progress, is slow and of a long-term nature (Lavee *et al*., 2003; Rallo *et al*., 2007, 2008). Thus, the potential of adapting physiologically, highly fruitful vigorous cultivars for an immediate use in hedgerow olive orchards required for saving labor and enhancing the economy of the olive oil industry might be of significant importance. Although uniconazol is presently apparently not authorized for application in fruit trees in the EU it could probably be licensed rather easily if required as its sister product paclobutrazol, as cited earlier, is widely used in horticultural tree crops including olives (Antognozzi *et al*., 1986; Navarro *et al*., 1989; Vossen *et al*., 2002).

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