

## **EFFECT OF HIGH DENSITY AVOCADO ORCHARD AND ROOT RESTRICTION ON YIELD**

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In the present work we will describe the primary results of dense orchards in which a very intensive concept for pruning and irrigation is being developed. The main stream of the concept is to control the tree volume by means of mechanical pruning and vegetative inhibition through the use of gibberellin synthesis inhibitors, producing compact trees (2,5 m high) with enough space between rows for good light not only in upper parts but also in those lower. Another important point regarding this concept is to create narrow rows for reducing the internal volume of trees under poor light conditions and low yield. The trees are controlled for a maximum height of 2.5 meters, allowing the harvest to be performed from ground level thus avoiding additional costs as a result of high efficiency. In two different trials we have 800, 1,250 or 1,670 trees per hectare. Some of the treatments restrict root volume by using a plastic barrier in the soil. The yield of the second and third season after plantation ranges from 17 to 30 tones per hectare. The primary results indicate that root restriction improves irrigation efficiency and helps to control the growth of trees.

**Key words:** avocado, high-density, root-restriction, yield

## **EFFECTO DE PLANTACIONES DENSAS Y RESTRICCIÓN DE LAS RAÍCES EN LA PRODUCCIÓN DEL AGUACATE**

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En el presente trabajo se presentan los resultados preliminares obtenidos en plantaciones densas en las cuales se han aplicado intensa poda y riego. La base de este concepto es controlar el volumen del árbol por intermedio de poda mecánica y tratamientos que incluyen el uso de inhibidores de la síntesis de giberelinas. Esto ha resultado en el establecimiento de árboles compactos de 2,5 metros de altura, con suficiente espacio entre hileras y buena iluminación no sólo en su parte superior, sino también en la inferior del árbol con fruta que es fácil de cosechar. De tal manera que se evitan costos adicionales producto de una mejor eficiencia.

Otro importante concepto es crear hileras de árboles estrechas para disminuir el volumen interior de árboles mal iluminados y menos productivos. En dos experimentos separados tenemos 800, 1250 ó 1670 árboles por hectárea. Algunos de los tratamientos incluyen una cobertura de plástico en el suelo que limita el volumen de las raíces. La segunda y tercera cosecha ha llegado a 17 - 30 toneladas por hectárea. Los primeros resultados indican que la limitación de

las raíces mejora la eficiencia del riego y ayuda a controlar el crecimiento del árbol.

High density orchard is being studied all over the world in many kinds of fruits as a method for getting precocious high yields and earlier economical balance. In the 70's several avocado orchards were planted with app 660 trees per hectare. The pruning concepts adopted by avocado growers were not fit for dense orchards, and as the trees developed the orchard which became too dense and lacked proper illumination showed a clear decline in yield. A much more intensive pruning regime was developed for avocado trees during the period of the 90's and the beginning of 2000's which included a number of prunings during the season and also the use of gibberellin inhibitors. In the present work we will describe the primary results of dense orchards in which a very intensive concept for pruning and irrigation is being developed. The main stream of the concept is to control the tree volume by means of mechanical pruning and vegetative inhibition through the use of gibberellin synthesis inhibitors, producing compact trees with enough space between roads for good illumination not only in the upper parts of the rows but also in the lower. Another important point regarding this concept is to create narrow rows with minimal under lighted volume of the tree. The trees are modulated for a maximum height of 2.5 meters allowing the harvest to be performed from the ground thus saving costs in work and input as a result of high efficiency. We will describe the primary results of two high density orchards one located in Ma'agan Michael and the other in Magal planted in July 2002 and 2003 respectively.

## MATERIALS AND METHODS

**Change in Trunk and fruit diameter, in relation to air temperature and relative humidity:** Data was collected through a Phytalk device of Phytech Ltd, which is based on a data logger, a computer program for the data display and a radio forecaster which passes data through internet to a far computer. The device included sensors for the meteorological measure of air temperature and relative humidity (THETA PROB from DELTA-T). Trunk diameter changes were measured by sensors based on LVDT (Linear Variable Differential Transformer), 'electronic dendrometers' from Phytech Ltd of the PHYTALK line, which measure micronic changes in the plant organ. The dendrometer is placed on a specific screw inserted deeply into the trunk, and the piston used for the measuring is adjacent to the trunk and changes its length according to the trunk diameter changes. The dendrometers are equipped with an electronic data logger and a forecaster for the data transmission through the internet to a far computer. Through PHYTALK a computer program from Phytech Ltd the trunk maximal daily contraction (MDC) was determined. The changes in trunk diameter measured by the sensors were consistent in their trend and scale.

**Ma'agan Michael:** The plot was planted in July 2002 with 800 Haas trees on Degania 117 canopy per hectar (5 meters between rows and 2.5 meters between trees on the same row) (Picture 1). In this trial we are comparing three treatments:

1. Regular irrigation with three non leak drip lines per row (40 centimeters apart from one another) with drips every 25 cm with a capacity of 1.6 liter/hour per drip.
2. Dense irrigation with 4 non-leak drip lines per row with similar drips as in treatment 1. There was 20 cm between one drip line to the other.
3. Dense irrigation with 4 non-leak drip lines (like in treatment 2) with root restriction by a plastic sheet in the soil perpendicular to the ground surface 0.5 m deep on both sides of the row forming a plastic canal without a bottom.

Every treatment was performed in at least 4 consecutive rows. The irrigation frequency changed from every 2-3 days during the passing seasons till 3 pulses of irrigation every day in the middle of summer.

According to the Jewish religion the first yield is forbidden to be eaten and it must be thrown. Only the third yield can be picked and sold. As a result we had to throw away all the yield we got in 2004. Before we threw the yield was evaluated at the middle of July 2004 by counting the fruitlets after the drop ceased and by multiplying the number of fruitlets by the average weight of a Hass fruit (about 220 gram per fruit).

There is a way out of this, using a method for growing the new plantlets in the nursery developed in 2003. According to this method the plantlets should be grown following certain rules so when they are planted in the grower parcel they are already considered to be one year old, so that in the second season the grower can already harvest his first commercial yield. Since this method was developed after the Ma'agan Michael parcel plantation we had to throw the second yield as we describe above. Even that it was important to evaluate the second yield before throwing it because avocado orchards planted from 2003 with plantlets grown according to the new method can be commercially harvested already in the second season after planting.

**Magal:** The plot was planted with Haas on Degania 117 canopy on July 2003. The space between rows is 4 meters. The roots were restricted in the same method used in Ma'agan Michael (see description above) in all the rows of the orchard. We used 4 non-leak drip lines per row with a distance of 15 cm between drip lines. The drip capacity was of 1 liter per hour. We compared two orchard densities in the present trial: (a) 1250 trees per hectare: where the distance between the trees in the same row was 2 meter. (b) 1670 trees per hectare: where the distance between the trees in the same row was 1.5 meter. Similarly to Ma'agan Michael, 4 rows were considered as a replicate with 6 replicates per treatment. The trees were irrigated according to Adato's non-stress concept (personal communication), using the maximal daily trunk

contraction (MDC) as a parameter for determining irrigation. According to this concept, irrigation rate and distribution are determined in order to achieve minimal trunk contraction. The irrigation was performed by 6 minutes pulses with 2 meter cube/hectare per pulse. During 2005, two years after planting, at the peak irrigation season the orchard was irrigated by 12 pulses, app 24 cubes per hectare.

## RESULTS

**Ma'agan Michael:** On May 2004, 22 months after planting, the rows were continuous with about 225 cm height (Picture 1). If we assume that by the middle of July the fruitlets are not expected to drop anymore, the average evaluated yield in 2004, app 30 months after planting, was 30 tones per hectare (Fig 1). Even if the evaluation of the yield by counting the fruitless is inaccurate enough the expected yield was very high for 2-year old trees.

In the third year, about 40 months after planting the first commercial yield was harvested in Ma'agan Michael (Fig. 2 and 3). The yield in the treatment irrigated with 4 drip lines was not significantly different from the one irrigated with 3 drip lines and was 18 tones per hectare and 16.5 tones per hectare respectively (Fig. 2). In contrast to that, the yield in the root restricted treatment was 24.2 tones per hectare. That is about 7.5 tones per hectare statistically significant higher than the treatment with 3 drip lines per row. We can say that the significant positive effect in yield is caused by the root restriction and not by the number of drip lines per row. The big size fruit yield in the restricted root treatment was not statistically higher compared with the other treatments (Fig. 3).

### **Irrigation efficiency**

The daily trunk maximal contraction (DMC) was lower in the root restricted trees throughout the season (Fig. 4). Those differences in DMC were more obvious during high stress weather with hot and dry winds, when the differences between the root restricted trees and the other treatments were the biggest (Fig. 4). Those results indicate a lower stress in root restricted trees as a result of a more effective irrigation.



Picture 1. High density Haas orchard with 800 trees hectar 22 month after planting on July 2002. Ma'agan-Michael, May 2004

Foto 1. Plantación densa de la variedad Haas con 800 árboles per hectárea 22 meses después del plantado en Julio 2002. Ma'agan-Michael, Mayo 2004

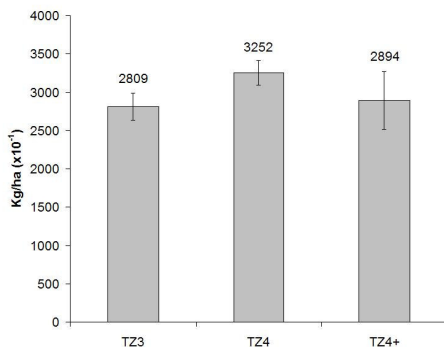


Fig. 1. Potential Yield calculated by counting fruitlets 24 months after the trees were planted multiplied by the average weight of Haas fruit size (220 gr per fruit), in the 2004/5 season. The orchard has 800 trees per hectare and was planted on July 2002 in Ma'agan-Michael and treated in three different regimes: (a) TZ3 –irrigation with 3 drip lines per row. (b) TZ4 –irrigation with 4 drip lines. (c) TZ4+ - irrigation with 4 drip lines and restricted root

Fig. 1. Producción potencial calculada contando el cuajado 24 meses

después del plantado y multiplicando por el peso promedio del fruto Haas (220 gr por fruto), en el año 2004/5. La plantación con 800 árboles por hectárea fue plantada en Julio 2002 en Ma'agan-Michael y tratada en tres condiciones distintas: (a) TZ3 – irrigación con 3 líneas de goteo. (b) TZ4 – irrigación con 4 líneas de goteo. (c) TZ4+ - irrigación con 4 líneas de goteo con restricción de las raíces

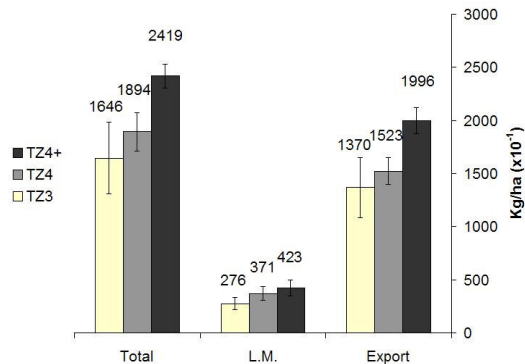


Fig. 2. Total, Local Market and Exported Haas yield 40 mouths after planting picked in the 2005/6 season. The orchard has 800 trees per hectare and was planted on July 2002 in Ma'agan-Michael and treated in three different regimes: (a) TZ3 –irrigation with 3 drip lines per row. (b) TZ4 –irrigation with 4 drip lines. (c) TZ4+ - irrigation with 4 drip lines and restricted root

Fig. 2. Producción total, del Mercado Local y Exportada 40 meses después de la plantación cosechada en la estación 2005/6. La plantación con 800 árboles por hectárea fue plantada en Julio 2002 en Ma'agan-Michael y tratada en tres condiciones distintas: (a) TZ3 – irrigación con 3 líneas de goteo. (b) TZ4 – irrigación con 4 líneas de goteo. (c) TZ4+ - irrigación con 4 líneas de goteo con restricción de las raíces

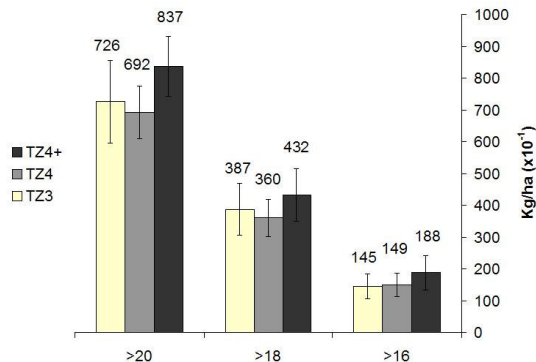


Fig. 3. Big size Haas fruit yield 40 mouths after planting picked in the 2005/6 season (>16 = fruits bigger than size 16 = 16 fruits in 4 Kg). The orchard has 800 trees per hectare and was planted on July 2002 in Ma'agan-Michael and treated in three different regimes: (a) TZ3 –irrigation

with 3 drip lines per row. (b) TZ4 –irrigation with 4 drip lines. (c) TZ4+ - irrigation with 4 drip lines and restricted root

Fig. 3. Producción de frutas grandes 40 meses después de la plantación cosechadas en la estación 2005/6 (>16 = frutas mas grandes que el tamaño 16 = 16 frutas en 4 Kg). La plantación con 800 árboles por hectárea fue plantada en Julio 2002 en Ma'agan-Michael y tratada en tres condiciones distintas: (a) TZ3 – irrigación con 3 líneas de goteo. (b) TZ4 – irrigación con 4 líneas de goteo. (c) TZ4+ - irrigación con 4 líneas de goteo con restricción de las raíces

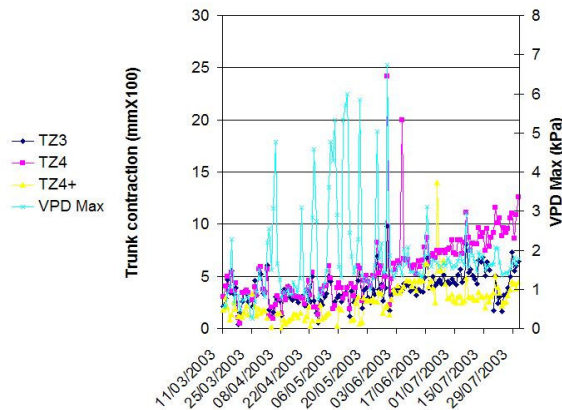


Fig. 4. The Maximal Daily Trunk Contraction between March and July 2003 in a high density orchard in Ma'agan Michael in three different regimes: (a) TZ3 –irrigation with 3 drip lines per row. (b) TZ4 –irrigation with 4 drip lines. (c) TZ4+ - irrigation with 4 drip lines and restricted root. The maximal daily vapor pressure deficit in the atmosphere was calculated (VPD Max)

Fig. 4. La máxima contracción diaria del tronco entre Marzo y Julio 2003 en una plantación densa de aguacate Haas en Ma'agan Michael en tres condiciones distintas: (a) TZ3 – irrigación con 3 líneas de goteo. (b) TZ4 – irrigación con 4 líneas de goteo. (c) TZ4+ - irrigación con 4 líneas de goteo con restricción de las raíces. El valor máximo de la deficiencia de presión de vapor en la atmósfera fue calculado (VPD Max)

### Magal

The first commercial harvest, 30 months after planting, yielded was 17 tones per hectare in 'Haas' variety (Fig. 5) and about 10 tones per hectare in 'Ettinger' variety (Fig. 7). No difference in yield was measured between the two orchard densities in 'Haas' (Fig. 6) and also in Ettinger (Fig. 8).

### DISCUSSION AND CONCLUSIONS

**Ma'agan-Michael:** The more effective irrigation in root restricted trees and the advantages in the yield should be tested for consistency in the following years. The fact that a determined constant volume of soil is irrigated with no relation to the season may have an intrinsic advantage more than physical ones. Regularly,



the irrigation rate that depends on the season reaches a climax in the middle of the summer. Usually in Israel, the winter is the rainy season and in the early spring the irrigation rate is relatively low due to weather conditions. With the rise in soil temperature the roots start to grow and spread out using the soil humidity of the rain. After the root flush and vegetative flush, the roots probably suffer a shock because they spread to regions not irrigated and so they are 'cut off' by the restricted irrigation. The thought is that this root 'cut off' can tremendously affect the tree: (a) the canopy that is supported by the roots suddenly gets 'less support'. (b) growth regulators, such as cytokinins, produced mainly in roots, that are crucial for the physiological processes such as fruit set, and cellular proliferation are also 'cut off'. The root restriction used in the present work ensures the irrigation of a fixed volume of soil and roots, avoiding such fluctuations in root volume that may be harmful for the tree and the developing fruits.

**Magal:** A relatively high yield was harvested in the experimental orchard in Magal compared with the traditional orchards two and a half years after the planting. We should follow the yield results in the next few years to determine the average yield per cube irrigation water and the economic balance of this very intensive planting with 1250 and 1670 trees per hectare and root restricted. Today, three and half years after planting, the 2.5 meters height rows are continuous, and the harvest is performed from the ground. The pruning strategy aims to maintain the rows with 1.5 meter width leaving a distance of 2.5 meters for the passage of a tractor facilitating the maintenance. It may be emphasized that the two treatments that are being compared in Magal are root restricted. The difference between them is the distance between trees in the same row. An interesting issue that emerges from the Magal work is whether the competition between trees in the same row will help to restrain the trees and make it easier to control the final volume of the tree. If this is the case the root restriction may help controlling the final volume of the tree. The answers for these interesting questions may be answered a few years from now.

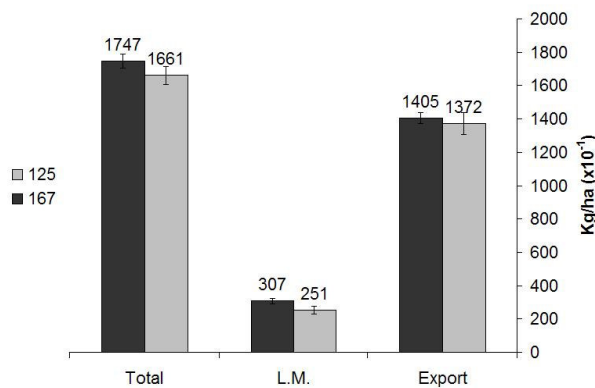


Fig. 5. Total, Local Market and Exported Haas yield 30 months after planting picked in the 2005/6 season in a root restricted orchard with



1250 trees or 1670 trees per hectare planted in July 2003 in Magal  
 Fig. 5. Producción total, del Mercado Local y Exportada de la variedad Haas 30 meses después de la plantación cosechadas en la estación 2005/6 en una plantación donde las raíces fueron restringidas con 1250 o 1670 árboles por hectárea plantadas en Julio 2003 en Magal

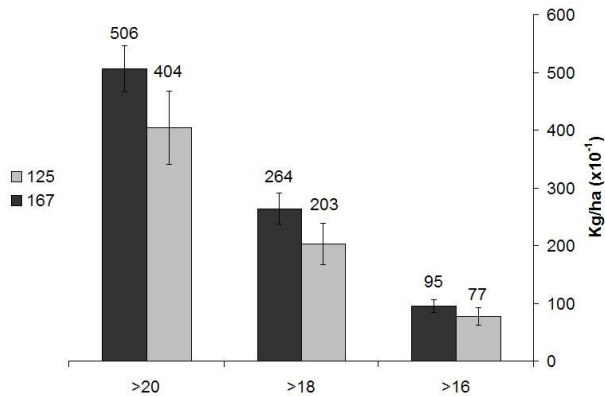


Fig. 6. Big size Haas fruit yield 30 months after planting picked in the 2005/6 season (>16 = fruits bigger than size 16 = 16 fruits in 4 Kg) in a root restricted orchard with 1250 trees or 1670 trees per hectare planted in July 2003 in Magal

Fig. 6. Producción de frutas grandes de la variedad Haas 30 meses después de la plantación cosechadas en la estación 2005/6 (>16=frutas mas grandes que el tamaño 16=16 frutas en 4 Kg) en una plantación donde las raíces fueron restringidas con 1250 o 1670 árboles por hectárea plantadas en Julio 2003 en Magal

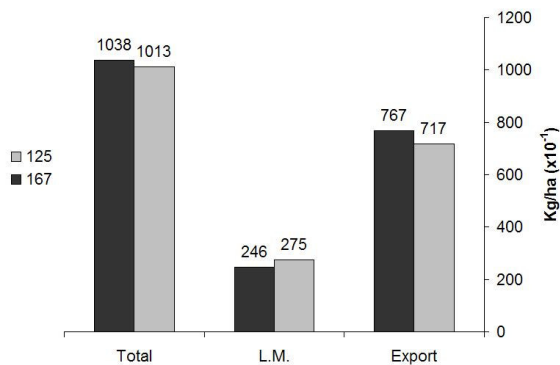


Fig. 7. Total, Local Market and Exported Ettinger yield 30 months after planting picked in the 2005/6 season in a root restricted orchard with 1250 trees or 1670 trees per hectare planted in July 2003 in Magal

Fig. 7. Producción total, del Mercado Local y Exportada de la variedad

Ettinger 30 meses después de la plantación cosechadas en la estación 2005/6 en una plantación donde las raíces fueron restringidas con 1250 o 1670 árboles por hectárea plantadas en Julio 2003 en Magal

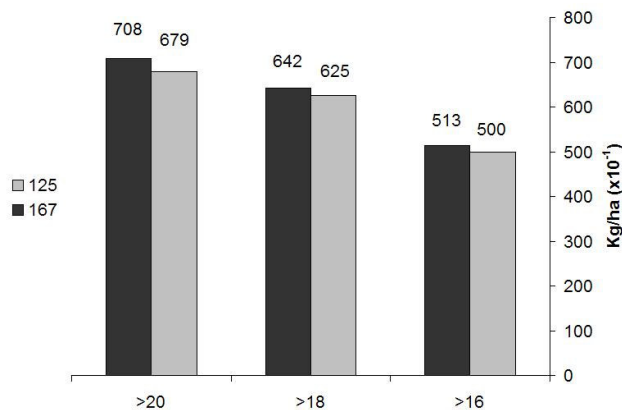


Fig. 8. Big size Ettinger fruit yield 30 months after planting picked in the 2005/6 season in a root restricted orchard with a density of 1250 trees or 1670 trees per hectare planted in July 2003 in Magal

Fig. 8. Producción de frutas grandes de la variedad Ettinger 30 meses después de la plantación cosechadas en la estación 2005/6 (>16=frutas mas grandes que el tamaño 16=16 frutas en 4 Kg) en una plantación donde las raíces fueron restringidas y con una densidad de 1250 o 1670 árboles por hectárea plantadas en Julio 2003 en Magal

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