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AVOCADO FRUIT GROWTH DURING WINTER THE IMPORTANCE OF IRRIGATION BETWEEN RAINS

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An exponential correlation between avocado fruit diameter and weight was determined for the Hass variety, allowing accurate determination of fruit weight without removing it from the tree. There is a significant increase in fruit weight during winter, reaching 31 to 43 grams per unit. Growth is inhibited at night-time by evapotranspiration conditions, and in some cases reduction of fruit weight may be observed. Sometimes, irrigation can prevent the inhibition effect on fruit growth. In the present work, we have tried to evaluate the importance of irrigation during winter and calculate the weight loss because of no irrigation between rain events.

Key words: irrigation, fruit, growth, winter, trunk, contraction

CRECIMIENTO DEL AGUACATE EN INVIERNO LA IMPORTANCIA DEL RIEGO EN PERIODOS NO LLUVIOSOS

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Se determinó una correlación exponencial entre el diámetro y el peso de la fruta de variedad Hass, estableciendo su peso sin desprender la fruta del árbol. Existe un aumento significativo del peso de la fruta durante el invierno, alcanzando entre 31 a 43 gramos por unidad. Las condiciones de evapotranspiración inhiben el crecimiento de la fruta durante la noche, e incluso conducen a una reducción del peso de la misma. En algunos casos, el riego puede prevenir este proceso de inhibición del crecimiento. En el presente trabajo, hemos tratado de evaluar la importancia del riego durante el invierno, y al mismo tiempo calcular la capacidad de crecimiento o la pérdida de peso de la fruta no regada como consecuencia de falta de riego entre lluvias.

Introduction

The fruit size is a major parameter in determining of the merchantability and the price of fruit. For a balanced and stable rentability, we need that at least 75% of the Haas variety will weight more than 200 gr. One of the ways to deal with the problem of fruit size is to pick selectively, letting the small size fruits to remain longer on the tree, allowing them to continue growing, getting closer or even

reaching the goal size. This counteracts the need to finish the harvest as early as possible to give the tree the time necessary to recover, for a good flower induction and to avoid a flowering delay and yield instability in the following season. Despite the negative effect of leaving the fruits on the tree late in the harvest season, this harvest management is very common among growers mainly for market reasons. In the present work we followed the size of fruit growth during the Israeli winter from December to March at three consecutive seasons. This work was performed in an adult avocado orchard of Kibbutz Ziquim located in the East-Northern part of the Neguev region near the Mediterranean Sea. The growing conditions of the Haas variety in Ziquim are one of the best in Israel. In the last 4 seasons, 60 to 75% of the fruits bigger than 200 gr, and had a mean yield background of 20 tons per hectare. These results are partly explained by the growing conditions: drained soil between light and loamy, about 1.5 kilometers off the sea, and chloride concentrations in irrigation water which do not exceed 80 mg per liter. The orchard is under a pruning management that allows a good penetration of light. The trees are irrigated according to Adato's non-stress concept (personal communication), using the diurnal daily contraction as a parameter for determining irrigation. According to this concept, irrigation rate and distribution are determined to achieve minimal trunk contraction. Following the good growing conditions is essential in order to determine the growth potential of Haas fruit.

Materials and Methods

This work was performed during three seasons – 2001/2, 2003/4 and 2004/5 - in an avocado orchard, cv. Haas grafted on West Indies canopy planted in 1981 with 286 trees per ha. The irrigation is through two Ein Dor mini jets per tree each one outputs 40 liters per hour. The irrigation frequency is changed during the season from one irrigation every two days during early spring and late autumn to every day with one to four irrigation pulses per day, according to weather changes during spring and summer. During winter, the maximum daily contraction of the trunk (MDC) was determined in periods between rains, and irrigation was proceeded in order to lower the MDC similarly to the summer criteria for irrigation.

Change in trunk and fruit diameter, in relation to air temperature, relative humidity and soil moisture: 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 and the volumetric moisture measure of the soil (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 measured plant organ. The dendrometer is placed on a special screw inserted deeply in the trunk, and the piston used for the measure 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 maximum daily contraction (MDC) was determined. For the

determination of the changes in the fruit size FI-3EA sensors also based on LVDT were used. The changes in trunk and fruit diameter measured with the sensors, were consistent in their trend and scale.
Weight/Diameter fruit determination: 30 fruits weighting between 105 and 342 gr each were sampled during 2004 for the determination of the ratio between fruit diameter and weight.

Results and Discussion

Weight/Diameter ratio: An exponential correlation was determined between fruit diameter and weight (**$Y = 0.2911*X^2-26.901*X+722.5$** , where Y is the fruit weight in gr and X is the fruit diameter in millimeters) with a high correlation coefficient (**$R^2 = 0.964$**), (Fig. 1). Thus the correlation formula of fruit diameter and weight allows us to evaluate fruit weight by measuring fruit diameter without picking it.

Winter fruit growth: The rate of fruit change in diameter during winter was determined and the change in fruit weight was calculated by using the exchange correlation formula (Fig. 2 – a, b and c). The yield in 2001/2, 2003/4 and 2004/5 was 22, 18 and 25.5 tones per hectare respectively. During those 3 seasons about 20% of the yield was harvested during December-January and the remaining 80% was harvested by the end of February. The fruit grew about 40 to 44 grams from the beginning of December to the end of February in a similar rate in all three seasons (Fig. 2 – a, b and c). The considerable fruit growth during winter occurred despite the heavy yield hold by the trees during most of the measured period since most of the yield was harvested during February. It might be that the fruit should have grown in a higher rate if a bigger portion of the total yield had been harvested earlier, but we do not have data to validate that.

The trunk and fruit diameter: A periodical contraction during day and expansion during night was determined for the fruit and the trunk. The periodical contraction/expansion in fruit and trunk was concomitant (Fig.3). The contraction during day seems to be caused by the inability of the tree to suck enough water through its root system to fill the water deficit caused by the evapotranspiration. At night, with the rise in relative humidity and lower temperature conditions, the tree compensates the deficit and can even grow, i.e. an increase in diameter achieving maximum early in the morning (Fig. 3). In deficit water conditions in the soil, the daily contraction rises and it is possible to decrease contraction by irrigation. Some of the avocado orchards in Israel use the trunk daily maximal contraction (MDC) as a parameter to determine irrigation, using the non-stress concept. According to this concept, irrigation rate and distribution are determined for minimal trunk contraction.

Rain amount and distribution during winter: The rain amount ranged from 200 to 442 mm in the three years during which this work was performed (Table 1). Among the 90 days between 1th December to 1th March, we had only 23 rainy days in winter 2001/2, 19 rainy days in 2003/4 and 25 rainy days in 2004/5 (Table 1). The data indicates that there are long periods, sometimes lasting many days, between rain events. Many rain events are with a few millimeters of rain (about 10

to 12 events with 1 to 5 mm rain, Table 1). At these conditions it may be a water deficit in the soil because of the long periods without rain.

Night Vapor Pressure Deficit (VPD) and fruit growth: The VPD changes according to ambient relative humidity (RH) and temperature. At low temperatures and high RH, the VPD is close to zero. The VPD rises with the ambient decrease in RH and rise in temperature, and so does the evapotranspiration. During most winter nights the RH is close to 100% (Table 1), and under those conditions the VPD is almost zero, i.e. there is no evapotranspiration during night. During the 90 nights between December till the end of February – 59 to 67 nights are with 100% RH (Table 1). In these conditions there is a complete recuperation of the trunk and fruit and also growth in which the diameter is bigger than in the day before. However, during the same period there were nights, when the RH during night was under 100% (Table 1), with conditions favoring evapotranspiration during the night. At conditions favoring evapotranspiration during night, not only is there no complete compensation of the water deficit in the trunk and fruit, but also they may shrink instead of growing during night, i.e. the fruit and trunk diameter decrease in comparison to the previous day. An example for such extreme conditions was in the nights between 3 and 5 of February 2005 (Fig. 4). At those nights the RH was under 85% and the VPD ranged from 0.5 to 0.8 Kilopascal (Fig. 4). At the morning of 3 of February the fruits diameters were 66.10 mm (green line at Fig. 4) and 65.45 mm (blue line in Fig. 4). Those fruits contracted during the day to 65.27 and 64.27 mm in concordance. During the night between 3 and 4 of February those fruits expanded to 66.01 (green line) and 65.27 mm (blue line). That is to say that the fruit diameter in the morning the 4 of February was smaller than in the 3 of February because there was not a full compensation of the fruit during the night, and at those conditions there was no net growth of the fruit (Fig. 4). The conditions of relative dry with considerable VPD during night continued also during the consecutive night, between the 4^{th} and 5^{th} of February (Fig. 4). During the day of the 4^{th} of February, some of the trees were irrigated with 20 m^3 per hectare. The fruits from the irrigated trees had a net growth of 0.15 mm during night (blue line in Fig. 4). In contrast, instead of growing, the diameter of the fruits from the non-irrigated trees decreased by 0.138 mm between the 4^{th} and 5^{th} of February in addition to the net decrease reached after the previous night (green line in Fig. 4). That is to say that the fruits from the non-irrigated trees in practice lost 0.288 mm, 0.15 mm for not getting net growth due to irrigation plus 0.138 mm for the net shrinkage due to non irrigation. The loss of 0.288 mm is equivalent to 3.25 gram, calculated with our correlation formula between diameter and weight, and that in a 24h day where there were evapotranspiration conditions during night. Every winter season, in all three years in which our present work was performed, we had about 11 to 12 nights with RH under 85% (Table 1), and 12 to 19 nights with RH between 85 to 90% (which we suppose that also favor evapotranspiration at a certain degree). At those conditions which favor evapotranspiration not only during the light hours of the day, but also during night, non-irrigation may null significantly the winter growth of the fruit.

Conclusions

1. It is possible to calculate the weight of a fruit by measuring its width with a coefficient of correlation (R^2 = 0.964).
2. The fruit grows significantly during winter but this growth is inhibited at nights with weather conditions that favor evapotranspiration and without a full compensation of the deficit of water in the tree produced during the day evapotranspiration.
3. Irrigation in those cases can not only null the inhibition of growth at conditions when evapotranspiration is favored during night, but also cause a net growth of the fruits.
4. When irrigating during the day before a night with evapotranspiration favored conditions and abolishing the growth inhibition of the fruit, the daily maximum contraction (DMC) decreases as a result of the irrigation. Therefore, the criteria used in the irrigation which is based on the minimal contraction of the trunk during summer is also valid for the winter in view of the close correlation between the periodic contraction/expansion of the trunk and the fruit.

	1 Dec 01 to 1 March 02	1 Dec 03 to 1 March 04	1 Dec 04 to 1 March 05
Irrigation (m3/hectar)	0	2,000	2,200
Rain (mm)	442	218	238
Days with 1 to 5 mm rain	10	12	10
Days with 5 to 10 mm rain	4	2	8
Days with 10 to 20 mm rain	0	5	4
Days with above 20 mm rain	9	0	3
Days without rain	67	71	65
Rainy days	23	19	25
Nights with 100% RH	59	63	67
Nights with RH range: 85-90%	19	15	12
Nights with RH under 85%	12	12	11

Tabla 1. Irrigation, total rain amount, number of rainy days, rain rates and nights RH during December, January and February of 2001/2, 2003/4 and 2004/5.

Tabla 1. Irrigación, cantidad total de lluvia, numero de días con lluvia, incidencia de lluvias según la intensidad y la humedad relativa en las noches durante Deciembre, Enero y Febrero 2001/2, 2003/4 y 2004/5

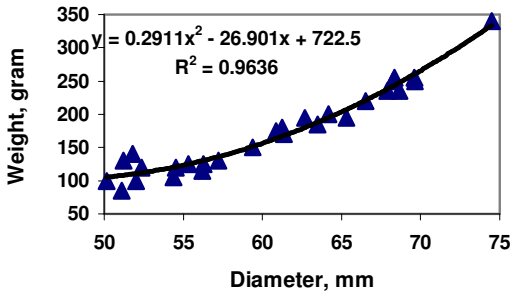
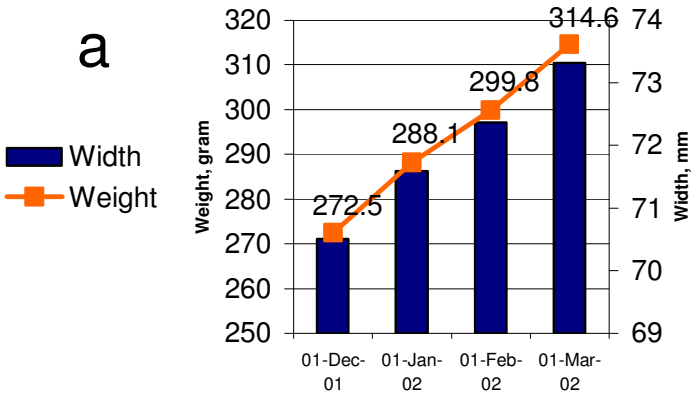


Fig. 1. Correlation between fruit width and weight in avocado Haas

Fig. 1. Correlación entre diámetro y peso del aguacate de la variedad Haas



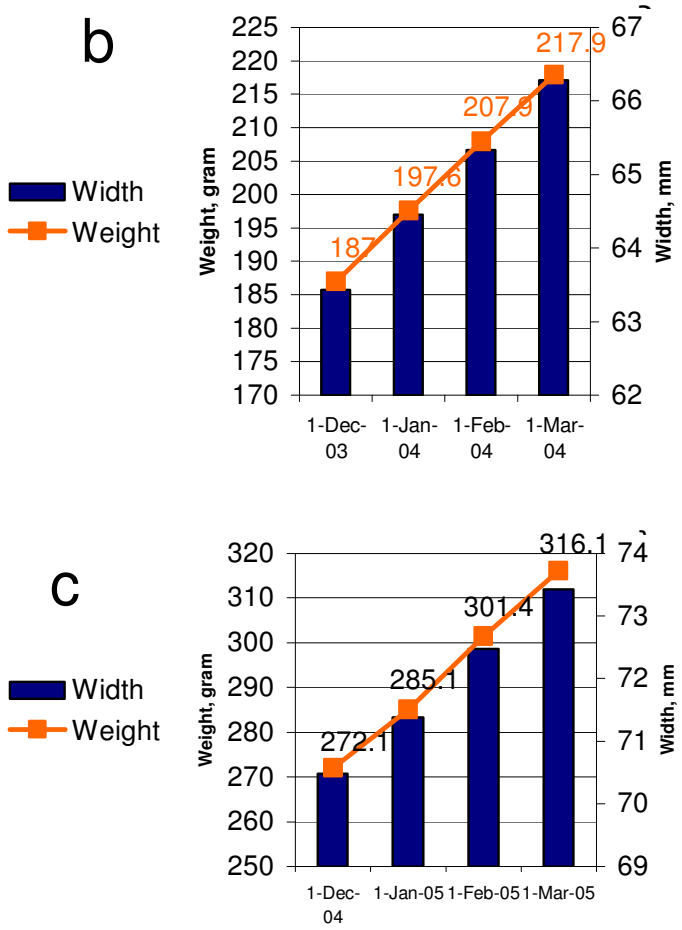


Fig. 2. Haas avocado fruit growth in Zikim between 1th of December and 1th of March at (a) 2001/2, (b) 2003/4 and (c) 2004/5

Fig. 2. Crecimiento de la fruta de aguacate en Zikim desde el 1ro de Deciembre hasta el 1ro de Marzo en (a) 2001/2, (b) 2003/4 y (c) 2004/5

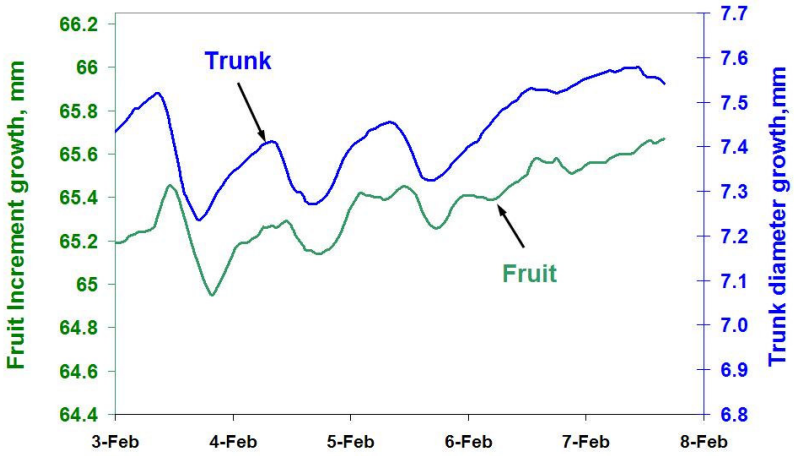


Fig. 3. Changes in diameter at the trunk (blue line) and fruit

(green line) of avocado Haas during the first week of February 2005

Fig. 3. Cambios en el diámetro del tronco (línea azul) y de la fruta (línea verde) en aguacate Haas durante la primera semana de Febrero 2005

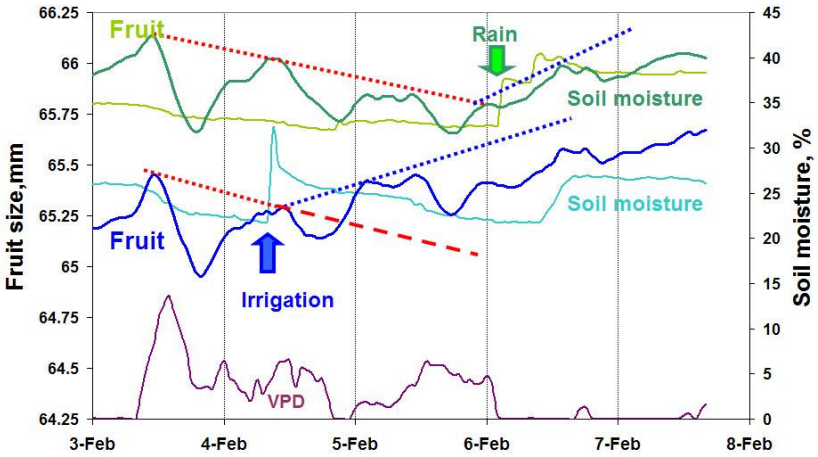


Fig. 4. Changes in the fruit diameter (dark blue and dark green lines), vapor pressure deficit in the atmosphere (VPD - purple line) and soil moisture (light green and light blue lines corresponding to the fruit diameter changes indicated by the dark green and dark blue lines) during the first week of February 2005

Fig. 4. Cambios en el diámetro de la fruta (líneas azul y verde escuras), deficiencia de presión de vapor en la atmósfera (VPD - línea violeta) y humedad del suelo (línea verde clara y azul clara correspondiendo con los cambios de diámetro del fruto indicados en color verde oscura y azul oscura) durante la primera semana de Febrero 2005