Irrigation management of apples
by continuous measurements of fruit growth
Field experiment, Kibbutz Zova orchard, summer 2000

M. Meron (MIGAL Galilee Technology Center, Kiryat Shmona) and Y. Harnam (Kibutz Zova)

Background

The annual irrigation regime of apples is generally planned according to evaporation co-efficients, which are based on yearly averages. During the season, corrections are made according to the actual evaporation and in response to irrigation indicators located in the orchard such as: tensionmeters, pressure chambers, manual measurement of fruit growth, each farmer according to his own personal preference and experience.

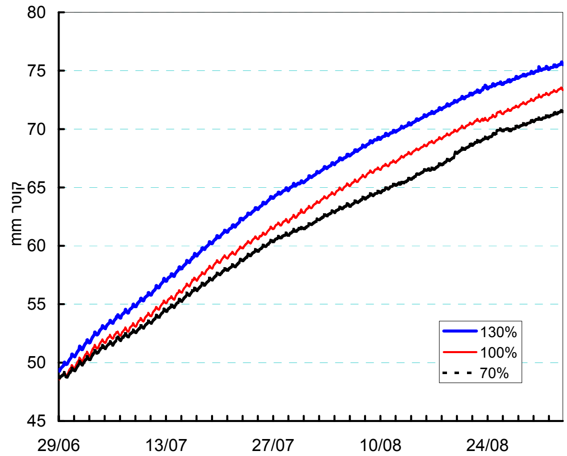
The importance of fruit size is that it characterizes the product's final quality, in addition to it being an irrigation indicator. The fruit's growth rate is dependant on the fruit-load and various climate stresses, i.e. evaporation demands and temperature, in addition to the soil water conditions. On the other hand, the plant's water demand in achieving quality production is also dependent on the fruit-load. Monitoring the fruit's size and its growth rate, give the farmer a strong tool for decisions on how to adapt fruit-load to irrigation possibilities, and to modify irrigation in order to reach maximum production with the highest quality.

Monitoring the fruit's size by traditional manual methods is labor intensive and is generally carried out just once a week, which reduces its effectiveness for immediate decision-making. The data collected describes the past and is often received too late for allowing corrections. In addition, there is the statistical inaccuracy of the last measurement which make difficult the prediction of future trends. Increasing measurements to twice a week is often beyond the capability of most farmers. Continuous measurements by electronical devices could supply real time data, and present it properly to enable immediate decisions.

Regulating irrigation by monitoring fruit growth can be done by referring to an optimal growth curve, and then by adjusting irrigation amounts so that fruit growth rates will be close to the optimum. Soil moisture is just one factor in fruit growth. The deviation from the curve is often caused by extreme climate conditions or fruit-load, and would not be possible to correct it by changing the irrigation regime. Lacking unique dependence of fruit growth on irrigation, Zova farmers developed a method of "internal reference" which neutralizes external effects by allocating partial rows which receive 30% less irrigation and others that receive 30% more irrigation. This method shows immediately if there is a positive response to increased irrigation amounts, or an expected damage to reduced irrigation, disregarding environmental or fruit load effects.

The purpose of this field experiment in the Zova orchard was to test the feasibility of irrigation sceduling using continuous electronic fruit diameter measurement and the internal "reference method" under actual conditions in a commercial operation.

Methods and Materials



In a five years old "Golden Delicious" orchards at Zova, a 25 meter section of the drip irrigation line was altered in order to receive a discharge of 70% and an adjacent section was altered to receive 130% of the regular irrigation. On the 30/6/2000, a "Phytomonitor" unit (Phytech Co., Yad Mordicai*) was installed, with four fruit diameter sensors attached to each of the three irrigation treatments: 70%, 100% and 130%. The unit was connected to a cellular telephone and the data was retrieved daily by telephone. The data was analyzed at MIGAL and was relayed to the farmers at Zova. On the same trees , 20 additional fruit were marked and measured manually once a week. "Representative" fruits were chosen visually to fit average sizes. Irrigation amounts were sheduled once a week, by comparing fruit growth ratesbetween the three treatments.

- The mentioning of the product's company is informational only and does not represent an endorsement.

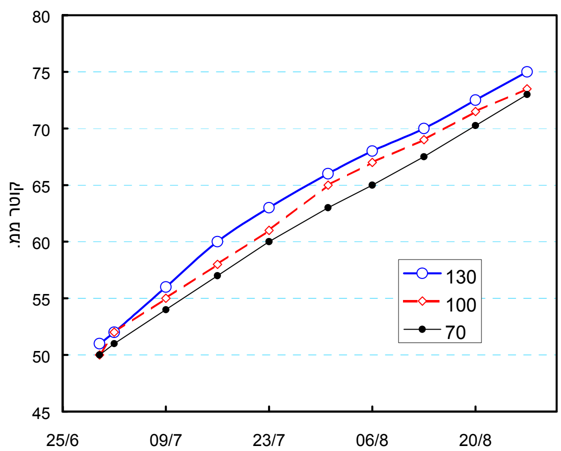


Fig. 1. Fruit growth progress with continuous measuring.

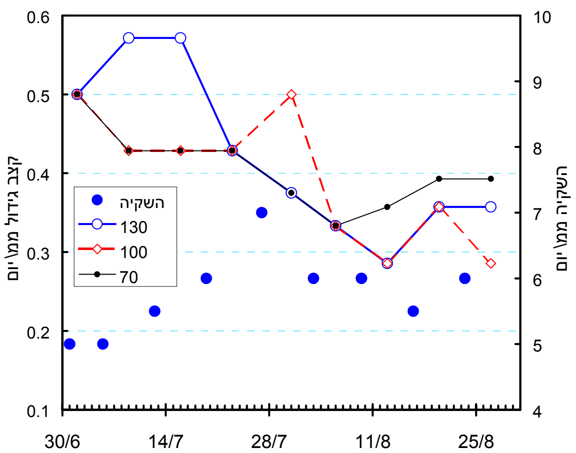


Fig. 2. Fruit growth rate, irrigation, and decision points.

Fig. 3. Fruit growth progress with manual measuring.

Fig. 4. Fruit growth rate with manual measuring and weekly irrigation.

Results

Fruit size. The fruit's growth curve (fig. 1), shows that the higher higher irrigation amount produced fruit that had a 2 mm. larger diameter than the regular irrigation amount, and that the 70% irrigation had smaller fruit. This represents a one third grade differences between the treatments. Fruit was no graded for each individual tree; therefore it's difficult to estimate how much the fruit size distribution of the sample represents the actual fruit size grades of the orchard. After steadying irrigation to 6 mm./day at decision point #3 (fig. 2), there was no advantage in over irrigationto obtain larger fruit size, and it's possible to conclude that an optimization of irrigation had been achivied for receiving the maximum fruit size.

Decision-making process. Sheduled by the initial irrigation table, 5 mm./day was applied in the beginning of July. During the first two weeks, it appeared that there was an advantege to the 130% irrigation in the fruit growth and therefore the irrigation was increased stepwise by 0.5 mm each week. At the decision point #3 the amount was increased by a larger step to 7 mm./day . After one week (decision point #4) the fruit growth slowed down as a result of extreme weather conditions. The additional irrigation had no effect and therefore the irrigation was reduced back to 6 mm./day. From this point onward, it was clear that there was no advantage to additional irrigation, and so the irrigation was kept at the same level or even reduced which is in contrast to the accepted practice of increasing the irrigation towards picking.

Comparison with manual measuring. Fruit growth by manual sampling (fig. 3 and 4) compared well to the electronic, being approximately 50 mm. in the beginning and about 73 mm. at the time when the electronic sensors were removed. Growth rates were similar in trend, but slight different in details. For instance, at decision point #3, manual samples show no advantage to additional irrigation while there was an advantage according to the continuous measuring. Also the differences in rates between 70% and 100% appear clearer with continuous measurement. It appears that the continuous measuring, in spite of the small sample size, represents more accurately the fruit size changes, and gives a clearer picture of the growth rates for irrigation decision support.

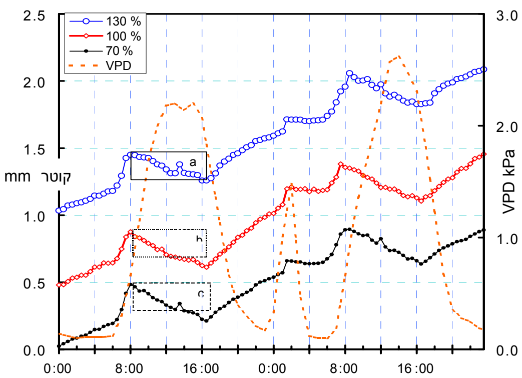


Figure 5. Diurnal course of fruit

Yield and irrigation amounts. The total yield in the orchard was approximately 4 ton/hectare. The fruit has yet to be sorted, however this year all the fruit in the orchard was larger than usual.

The irrigation amounts (mm.) per month and in total were:

May	June	July	August	September	May-September
76	121	180	192	107	676

In the last six weeks of the season, there was a water savings of roughly 40 mm., by irrigating according to 5.5-6.0 mm./day instead of 7 mm./day which is the normal practice close to picking.

When and how does the fruit grow? A close-look at two days of fruit growth (July 16 and 17, fig. 5) shows that the fastest fruit growth occurs between sunrise and 8:00. From that time onward the growth stops and the fruit begins to shrink. This process continues until the late afternoon, when the water that has been drawn out, begins to return from the trunk to the fruit. The fruit regains to its former volume with dusk and during the night adds on the daily size increment. A particular occurrence of extremely high VPD during the second night slowed down fruit growth.

The influence of irrigation on fruit growth is demonstrated in fig. 5 by the rectangle **a,** which shows the period of shrinkage and the extent of shrinkage with the 130% irrigation treatment. Comparing rectangle a with the others (**b** and **c**) in the lower irrigation treatments, we see that the size and duration of the shrinkage is greater in the reduced irrigation. The following day (hotter and drier = higher VPD), all the treatments had longer and deeper shrinkage. Here is a demonstration of the difficulty in employing absolute reference values of shrinkage or of growth, and the advantage in working with internal references.

Summary and conclusions. In the Zova orchard in the season of 2000, managing irrigation according to fruit growth was tested. Fruit size was measured on sections that were irrigated with 70%, 100% and 130% of the irrigation in the whole orchard, by two methods: continuous measurement with electronic sensors and weekly measurement manually. A good correlation was found between the two fruit size, measurement methods, despite the differences in the sample size. Irrigation was scheduled in response to the fruit growth rates as a result of more or less irrigation. Resulted water amounts were higher compared to the planned ones during the month of July, and were lower than planned during six weeks of August and September. Irrigation sceduling of apples by feedback of continuously measured fruit growth rates was shown to be feasible under real conditions in the Zova orchard.