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Cooling irrigation as a powerful method for microclimate modification in apple plantation

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Summary: Irrigation in some countries is a horticultural practice mainly used only to supply water. At the same time the use of micro-sprinklers have a powerful influence on the changes of temperature in orchards. When the air's temperature is high (about 20 °C or higher) the evaporative cooling irrigation significantly decreases the plants' surface temperature and air temperature. The cooling effect is stronger when the air is dryer. By using cooling irrigation regularly, canopy temperature can be decreased so that the beginning of blooming can be delayed. Also if the blooming is early and frost probability is high, serious damages can happen in orchards. The beneficial effect of cooling irrigation is the temperature reduction and frost protection. In March 2010, one month earlier than the expected blooming an irrigation system was established to produce anti-frost treatment and regulate the micro-climate of a Gala apple orchard which belongs to the University of Debrecen (Hungary). The objective of sprinklers was to cool the air by increasing water evaporation and relative humidity. The position of the micro-sprinklers was planned in three levels (around the tree trunks, a few cm near to the soil surface, in the crown region and above the crown, a half meter higher). The results showed that the water sprayed in the orchard by micro-jets influenced decisively the temperature of the plantation. At higher temperatures (around 20 °C), the drop of temperature may attain 5–7 °C. A low relative humidity of the air may increase the relative effect. When water was applied at intervals of 15 minutes for ten times a day from 8 am to 18 pm. the air, flowers and bud's surface temperature could be kept low. At certain days when the temperature was higher than 10 °C, irrigation was used at night time in similar 15 minutes intervals, from 18 pm and 6 am. The beginning of bloom could be delayed for more than ten days. The Gala apple variety blooming dynamics was characterized by a logistic curve in the treated as well as in the control plot. In the treated plot, the curve was steeper than in the control one in spite of the equal temperatures measured in the plots. Under Hungarian climatic conditions, the method was successfully used to delay blooming dates. The main result was the diminution of the frost damage in the spring that assured apple yields.

Keywords: Evaporative cooling irrigation, microclimate modification, delay of blooming, apple orchard

Introduction

Micro irrigation is a horticultural practice mainly used to supply water to the orchard. Nevertheless the micro sprayed irrigation has a powerful influence on fruit microclimatic parameters as temperature and air humidity. When the air temperature is high (about 20 °C or higher) the evaporative cooling irrigation significantly decreases the plant surface temperature. The cooling effect is stronger in that case when the air is dryer. By using the cooling irrigation frequently the temperature of the canopy (both bud surface and ambient air temperature) can be decreased so the speed of physiological processes will be slower and will result in later blooming of fruit trees. In the case of early blooming varieties the probability of climatic frost is high and can cause serious damages in orchards. The cooling irrigations beneficial effect comes forward to the temperature reduction and frost protection.

Below the freezing point the coexistence of water and ice provides for the flowers that the surface temperature remains

around 0 °C, while the temperature of the surrounding air falls to even –8 °C . Frost protective irrigation is a more wide-spread horticultural practice than cooling irrigation but with the use of cooling irrigation the protection against frost could be significantly escalated.

The dynamics of bloom influenced by the seasonal temperature were examined earlier in apple and sour cherry plantations by Lakatos et al. (2006, 2008, 2009). The effects of over-tree sprinkler irrigation on colorization by cooling 'Sensation Red Bartlett' pear were analyzed by Dussi at al. (1997). Those authors stated that fruits from cooled trees were more red and less yellow than fruit from noncooled trees, resulting in lower hue values by the middle of the harvestable maturity period in both years of study. Accordingly, cooled fruit should be harvested earlier than noncooled fruit to maintain postharvest quality. Differences between cooled and noncooled fruit with respect to hue, surface blush, and rate of firmness loss were more pronounced in a warm season requiring frequent cooling than in a cooler season.

The latest researches on the topic of micro-climate modification in the orchards are trend to analyze the effect of the evaporative cooling irrigation on fruit quality parameters (Iglesias et al., 1999; Iglesias et al., 2002). By using micro jets above the canopy at least two times a day the cover colour of fruit will get better (Iglesias et al., 2005). Furthermore the evaporative cooling irrigation is suitable for improving the anthocyanine content of the fruit as well (Dussi et al., 1995; Greene and Autio 1993; Iglesias et al., 2008).

The aim of this research work was to investigate the effects of evaporative cooling irrigation on orchard micro-climate parameters. We wanted to know how we can modify the daily distribution of temperature inside the tree canopy. We wanted to analyze the effect of evaporative cooling irrigation on the dynamics of blooming and how many days we can delay the start of blooming at the researched Gala apple variety.

Materials and methods

The effect of evaporative cooling irrigation on the blooming dynamics of apple of three irrigated and non-irrigated apple trees was analyzed. The rate of flowering is the ratio of open and not open flowers. It was observed on 3 trees, 100 flowers per tree separately, the flowers were counted day by day whether they were open or not. In the following we use the average of the flowering rates of these three observed trees. We analyzed the effect of micro-spraying on the daily distribution of tree surface temperature on windy nights and days, when the average wind speed was higher than 10 m/s. We also investigated the effects of evaporative cooling irrigation on those nights when the relative humidity was lower than 75%, the wind speed was lower than 3 m/s and the temperature was higher than 10 °C, and on those days when the daytime maximum temperature was higher than 20 °C and the average wind speed was above 10m/s separately.

Experiments were performed on the Experimental Farm of the Debrecen University, Pallag, Hungary. Measurements refer to an apple plantation with a 5×3 m planting design and trained to slender, spindle-type tree system (1666 trees/ha). The apple variety was “Gala”, planted in 1994.

A special station equipped with thermometers performed measurements with high sensitivity platinum sensors mounted on the branches of the trees near to the buds. The sensors were distributed in the crown at five points, in the center and on the four cardinal directions on the periphery. The sampling time was 10 minutes for each.

The dynamics of bloom were studied according to the system described by Nyéki (1980, 1989, 1990, 2002).

Experiments started in March 2010. Irrigation system was established for the purpose of producing anti-frost treatments and regulating the micro-climate. The role of sprinklers was primarily the prevention of frost damage; contrarily in the present program the goal was to cool the air

by increasing evaporation and relative humidity

The treatment began nearly one month prior to blooming. The position of the micro-sprinklers was planned at three levels: around the trunks, a few cm above to the soil surface, in the crown region and one half meter above the crown. We have used the micro sprinklers to irrigate 3 adjacent trees. In the case of cooled trees the flowering datum displayed in the results session refer to the average of the 3 trees. The meteorological station was placed on the crown of the cooled middle tree in order to minimize the effect of unirrigated trees' microclimate.

The program started the sprinklers every 60 minutes for 15 minutes, water was applied at intervals of 15 minutes for ten times a day from 8 am to 18 pm.

The retarding effect on blooming by cooling irrigation was measured on three selected trees and as a control group on three dry trees.

Measurements were made to register the three levels together. Irrigation happened in 3 height levels simultaneously. In that way the whole surface of the stem and crown was cooled together simultaneously in order to get the highest cooling efficiency. During the first year of the research program no device to measure the amount of water used for irrigation was placed thus there is no data available on the water output of the micro sprinkler system. Next year we will continuously measure the amount of water used by the micro sprinklers. Only in the case of examining the rate of blooming and the blooming delay did we set irrigational plots at 3 adjacent trees. In the cases of meteorological parameters we measured only 1 cooled (the middle one of the 3 cooled trees) and 1 control trees' (the middle one of the 3 control trees) microclimate as significant difference cannot be measured between the 3 adjacent cooled trees as well as between the 3 adjacent control trees because of the small distance.

Results and discussion

The evaporative cooling irrigation is a useful method for fruit colorization and for blooming delay (Iglesias et al., 2005, Dussi et al., 1997). But the over-tree micro sprinkle irrigation has a dangerous effect on plant protection, especially in those regions where the climate is not so dry. Funguses, bacteria spread faster and cause different plant diseases if the air humidity around the tree is constantly high. We should analyse in the future economically the cost of irrigation, risk of plant disease, spraying cost and the advantage of higher fruit quality (better fruit colour, higher sugar content). The efficiency of evaporative cooling irrigation is high in those areas where the temperature and wind speed is high, the air humidity is low. At humid climatic circumstances, where the annual amount of precipitation higher than 800 mm, it is not worse to use it.

The cooling effect was uniform in the whole space of the crown. The effects of the various levels were not observed immediately, because the evaporation was not intense during

this period, and the cooling activity was extended to the entire crown. The greatest effect was due to contact-evaporation on the wet surfaces.

During one month period, the temperature of the crown space of the sprinkled trees was 1.5–2.0 °C lower than in the non-cooled check (Figure 1). Around noon, the difference was even 3 °C. The smallest difference was in the early morning hours: 0.5–1.0 °C.

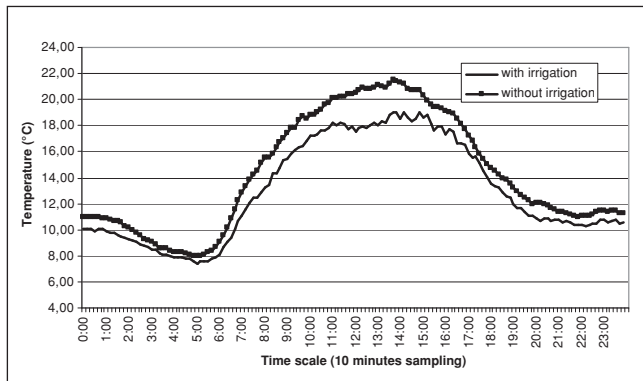


Figure 1: Mean daily temperature in the apple plantation with and without irrigation between March 15 and April 15, 2010

Although at night time there was no actual solar radiation for an intensive evaporation because of the high wind speed the process was working properly on those nights when the temperature was above 10 °C and the average wind speed of the nights was higher than 10 m/s (Figure 2.). The surface temperature at the irrigated trees was 3–3,5 °C lower than non-irrigated ones thanks to the relatively high temperature and wind speed. At low temperatures and doldrums the evaporation is less intense.

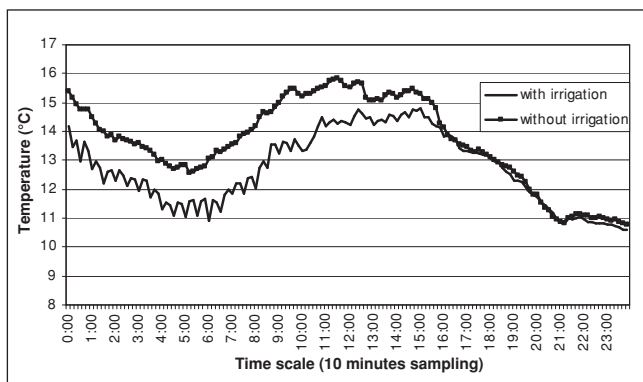


Figure 2: Effect of irrigation those days when the night temperature ($T > 10$ °C) and wind speed (Average > 10 m/s) was high between March 15 and May 15, 2010

It is well known that those days when the wind speed is lower than 3m/s the evaporation is not so intensive because the saturated air mass can slowly flow from the wet surface. The high temperature is suitable for intensive evaporation because the speed of water molecule is higher so its bigger kinetic energy helps the molecule to come out from the water surface easily. Those days when the temperature attained at

least 20 °C at daytime the effect of irrigation on the daily distribution of temperature was intense. On the basis of low wind speed and high temperature it can be stated, that the highest difference between the irrigated and non-irrigated apple plantation can reach 4 °C at noon (Figure 3).

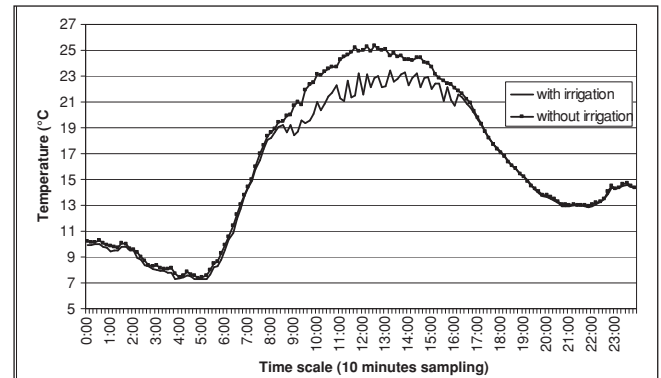


Figure 3: Irrigation effect on the daily distribution of temperature those days when the wind speed was lower than 3m/s and temperature was higher than 20 °C – from March 15 to May 15, 2010 .

Not only was the high wind speed able to improve the intensity of evaporation but the relatively low air humidity as well. In lower air humidity cases the unsaturated ambient air can absorb many water molecules easily. So the speed of water molecule is higher in those cases when the relative humidity of the air is low. We analyzed separately those nights when the air humidity is not so high (less than 75%) in that nights there were suitable circumstances for evaporation. The highest difference in temperature between the irrigated and non-irrigated apple plantation can reach 3,5 °C at midnight (Figure 4).

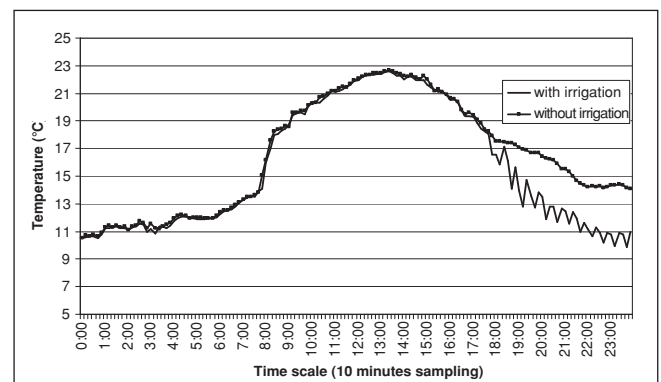


Figure 4. The effect of night time irrigation on the temperature of the apple plantation on the day when the air humidity was below 75% 2nd of May, 2010

The most conspicuous effect was experienced on those days when the maximum temperature was above 20 °C and at the same time there was an intensive solar radiation and the wind speed was higher than 10 m/s, at daytime the irrigated buds were 6–7 °C cooler than the non-irrigated ones (Figure 5). If during the research period there had been same weather circumstances as mentioned above several times, the bloom delaying effects of irrigation would had been more efficient.

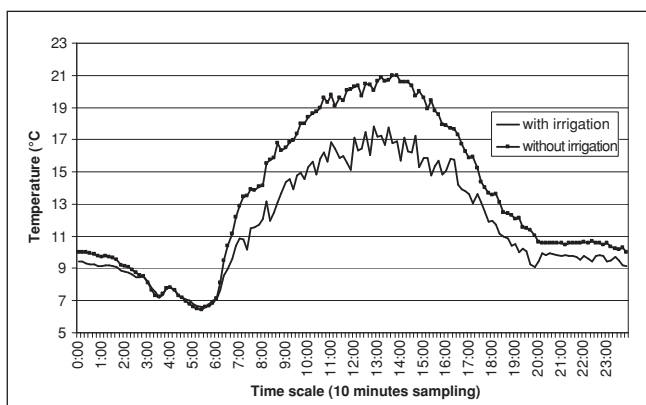


Figure 5: The effect of daytime irrigation on the daily distribution of temperature in apple plantation on a windy day when the average wind speed was higher than 10m/s. 29th of April 2010

On warm days, when the maximum temperature reached 20 °C, there was an intensive solar radiation and low wind speed-less than 3 m/s- and at the same time the relative humidity of the air was less than 50% at noon, the daily distribution of temperature showed intensive fluctuation (Figure 6). By usage of micro sprinklers the bud surface showed a decreasing of relatively high temperature (2–2,5 °C) within short intervals.

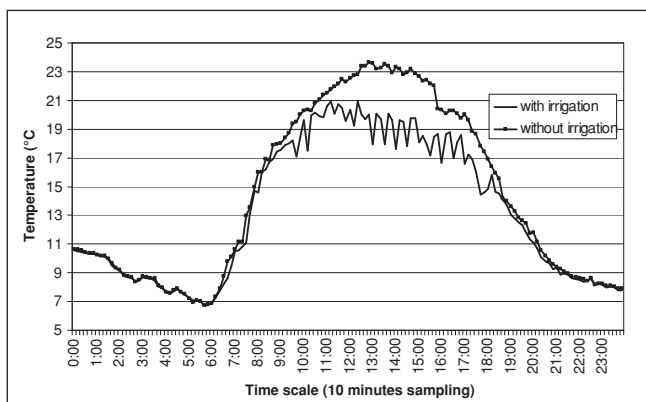


Figure 6: The effect of daytime irrigation on the daily distribution of temperature on the day, when the wind speed was lower than 3m/s, and the relative humidity less than 50% at noon- in apple plantation. 23rd of April 2010.

Irrigation not only lowered the temperature when it was below 10 °C but also moderated its fluctuation. On those days, when the sky was cloudy and the temperature was low, we could not find significant differences between irrigated and non-irrigated trees' surface temperature. Irrigation diminished the process of warming up and cooling down, thus the risk of heat-stress and sunburn can be reduced.

Non- irrigated trees started blooming at April 14–15, whereas the irrigated trees by 9–10 days later. In Figure 7, the rising angle of the sigmoid-curve was less steep. The time between start of bloom and full bloom lasted 16 days instead of 13 days in the check. The slowing down of the dynamics lasted during the whole blooming period. The dry check finished bloom at May 3 whereas the irrigated at May 12, but the whole blooming period was prolonged by 2 days.

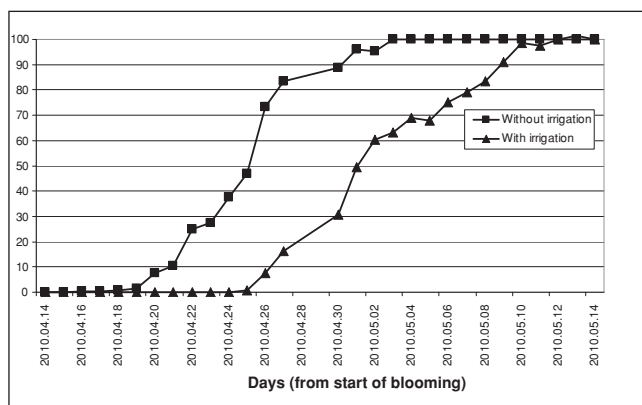


Figure 7. The effect of irrigation on the blooming dynamic of apple. Between April 14 and May 14, 2010

Conclusions

The micro-sprinkler irrigation is a suitable method for modifying microclimate in orchards (Dussi et al., 1997). The evaporative cooling effect of the irrigation mainly depends on weather circumstances. When the temperature is higher than 10 °C, there is a significant evaporative cooling effect. If the wind speed is less than 3 m/s the evaporation is not so intensive, the cooling effect is lower and not so efficient than in those cases when the wind speed is higher than 10 m/s. On windy days, in spring time, the intensity of evaporative cooling irrigation is 1,5–2 °C higher than on those days when the wind speed is below 3 m/s. The relative humidity of the air is also important in the evaporation. On those days when the relative humidity was about 50% at noon the evaporative cooling effects' intensity was 1–1,5 °C higher than on those days when the humidity was above 75% at early afternoon. The evaporative cooling irrigation was a useful procedure for delaying the start of blooming of Gala apple variety. The time delaying can reach 8–9 days. By this method, frost damage probability can be decreased by more than 70%, because climatically the frost occurrence at this time of the year is less by 70% at least.

Acknowledgement

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