International Journal of Horticultural Science 2008, 14 (1–2): 7–11
Agroinform Publishing House, Budapest, Printed in Hungary
ISSN 1585-0404

Microclimatic studies on different aged apple plantations

Lakatos, L.[1], Gonda, I.[2], Szabó, Z.[1], Zhongfu, S.[3], Wang,Y.[3] & Nyéki, J.[1]

[1]University of Debrecen, Istitute for Extension and Development, H-4032 Debrecen, Böszörményi st. 138 Hungary, E-mail: lakatos@agr.unideb.hu
[2]Department of Horticulture and Plant Biotechnology H-4032 Debrecen, Böszörményi st. 138 Hungary E-mail: gonda@agr.unideb.hu
[3]Chinese Academy of Agricultural Sciences, No.12, Zhongguancun South Street, Beijing 1000081, P. R. China E-mail:sunzf@263.net

Summary: The purpose of measuring parallel canopy and out of canopy microclimates was to find out in what extent climatic parameters measured in different aged canopis differ from each other and from the values characteristic to out-of-canopi areas. The importance of phytoclimatic researches seems to lie in the fact that if the reactions of fruit trees towards meteorological elements are continuously followed, we have the possibility to provide growers with information. These pieces of information are like defining the optimum time of phitotechnical interventions (summer pruning, sorting sprouts, thinning fruits, etc.), the necessity of applying mulching, defining the method and time of irrigation and applying plant protection activities. By means of phytoclimatic researches, it is possible to react to unfavourable meteorological impacts within a certain extent. It is also possible to successfully reduce the risks of late spring and early autumn frost damage, as well as the risks, content and measure of experienced heat and water stress conditions by finding out about the physical characteristics of the canopis' internal area.

Key words: apple cultivars, night and day temperature, cover colour, summer ripening, autum ripening, winter ripening

Introduction

Nowadays phytoclimatic researches have become a very popular and widely interested research trend. For the establishment of plant models' environmental details, it is inevitable to measure within the canopy itself. To receive reliable, punctual and continuous survey data, it is important to set registers in several measuring points on the fruit tree plantations, both horizontally and vertically. The measuring points have to reflect the atmospheric values characteristic to the canopy's natural envirnment – position, planting time and composition of variety. The time change, development, ceasing, content and dynamics of these can only be measured from more points and with a several layer measuring system.

In Hungary plant phytoclimatic researches started in the '50s. By means of the work of researchers from the University of Debrecen, *Berényi* (1952, 1953), *Justyák* (1957, 1960), *Szász* (1956), the characteristics and physical features of phytoclimatic researches became widely known. In the '60s several studies were published about the analyses of macro and microclimatic effects on the growth of fruits in grapeyards' and orchards' phytoclimate *Bognár & Kozma* (1961) and *Szász* (1961) – and comprehensive evaluation came to light about the role of agromerology on Hungary's fruit growing *Nyujtó* (1965). The studies published at the end of the sixties mainly examined apple and grape cultures *Csöbönyei & Stollár* (1969). These results effectively improved orchards' fruit safety and helped to find out about the fruiting capacity of different cultivars. In the '70s several research results were published revealing the relationship of fruit growth and dry matter content and weather were.

In the '80s more and more emphasies were laid on the description of meteorological background on variety-specific habitat *Stollár & Zárbok* (1981), heat and solar radiation supply of canopy *Dunkel* et. al. (1981), and the effects of critical winter temperature on orchards' overwintering (examining mostly grape cultures) *Dunkel & Kozma* (1981), *Csapó* (1984).

By means of the research results, the information base that meant the base of the development of phytoclimatic researches was created. In the '90s the dynamics of canopy's heit shortage and heat surplus meant the subject of most phytoclimatic researches *Kocsis & Ligetvári* (1992). In Hungary, however, most phytoclimatic researches so far have been related to plough-land cultures (*Anda*, 1993, *Hunkár & Bacsi*, 1993). In recent years we could read about the results of phytoclimatic researches in the work of *Tőkei* et al. (1995), *Lakatos* (2002), *Tőkei & Dunkel* (2004).

Material and method

The examined area was the apple plantation of Kasz-Coop Kft. (Ltd), Derecske. On the slim spindle-shape plantation the difference between lines and stocks is 4 m × 1 m (2500 pcs/hectare).

The plantation has different canopy structure planted in different time. Regarding their ages, the stock consists of 16 hectares of 3-year-old, 16 hectares of 6-year-old and 18 hectares of 9-year-old canopies.

The meteorological measuring system was developed in Hungary and is mounted with 24 channels and SM2 data logger, and high-sensitive and punctual (temperature humidimeter) sensors placed in 3 atmospherical levels (50 cm, 120 cm, 250 cm). We measure speed and wind direction details directly above canopy area, in 250 cms height. Radiometers were placed in the crown area of the canopy, and they are used for measuring global radiation as well as balance of radiation. The rain gauge with weighing gauge is placed in the trunk area. In this way the decline of canopy radiation and the extent of interception can be calculated, too.

In the soil, temperature is measured for soil's heat flow studies in 3 depth levels (5 cm, 30 cm, 60 cm).

In the present study the measuring results of the period of 1 April and 31 October, 2004. and conclusions deriving from the results will be presented. Average daily courses were maintained on the basis of the hourly survey data of this growing season. We examined in the different-aged appletree canopies how different height, thickness and density of tree deriving from the age of the tree influences temperature, humidity and radiation terms within the canopy. In all three examined plantations the meteorological measuring instruments were set up among 'Golden Reinders' cultivars. So as to avoid side sprouts, the measuring stations were set up 25–30 metres further in from the beginning of the line. The ages of canopies belonged to the following categories:

I. plantation : 9 years old
II. plantation : 6 years old
III. plantation : 3 years old

With the help of temperature and humidimeters placed in the 3 canopy levels (trunk area, crown area and the area above crown level) it is possible to study the daily terms and dymanics of heat and humidity movement from the soil surface to crown level and from the crown area to the soil and to the area above canopy.

It is characteristic to the slim, spindle-shape crown form used on intense plantations that the central axis forming the extension of the trunk means the dominant, determining part of the tree, and fruit growth takes place on the thin, diverge twigs. Simplified crown shape and dominant axis play a very important physiological and growing advantage. Due to the closeness of the nutrition chain, blooms and fruits are provided with nutrient in a better way. Moreover, because of the thin crown shape, solar ray utilization is more perfect regarding both height and depth than in case of more extended trees with bigger crowns.

On the other hand, smaller-size crowns trees may have a greater risk in relation to climatic effects, compared to more extended trees with bigger crowns. In case of more extended trees with bigger crowns there are more internal protected parts, and at radiating frosts less volatile and more shaded crown, which may mean a greater protection in case of delivered frosts as well. In case of more intense crown shapes, both the risks of radiating and delivered frosts are greater, and the possible harmful effects of solar radiation also appear more intensely. As a result of the size and shape of the trees, they are more and more exposed to meteorological effects, relating to growing parts, blossoms as well as fructification. In intense, small crown-sized orchards, the chance of radiating frost damage increases due to the thinning canopy, however, due to the shape and form of the tree, more favourable and through solar radiation can get through the crown, which, to some extent, can compensate for the unfavourable results of extreme meteorological effects made on the fruit trees.

In respect to heat, humidity, beam and nutrition supply the fruit trees belong to the kind of substance, which has different characteristics compared to the traditional natural surfaces (which usually means grass or lawn surface). These differences mostly depend on the canopy structure, density, height, age and water supply. Depending on territorial extension, phytoclimate means a micro or meso climatic unit, where significantly dissimilar conditions to macro climate can occur.

Results

According to temperature and humidity data measured on the plantations and out of plantations, the following statements can be done:

Area above crown

In the small hours, the extent of heat shortage increases in direct ratio to the growth of density and age of fruit trees, compared to out of canopy area (*Figure 1*). In the daily hours heat surplus can be experienced in the late morning hours and it can only be observed in connection with the older trees with bigger leafage, and in the afternoon and evening hours heat shortage can be experienced again in connection with the area above crown.

The degree of heat shortages reaches 2–3 °C, while heat surplus seems to be only 1–2 °C in the area above crown.

Humidity surplus characterizes the daily course of relative humidity in the early morning and afternoon hours, while in the late morning and early afternoon hours humidity shortage can be experienced (*Figure 2*). The humidity surplus of early morning hours can reach 15–18%, while the humidity shortage of daily hours cannot surpass 6–8% even in case if older trees.

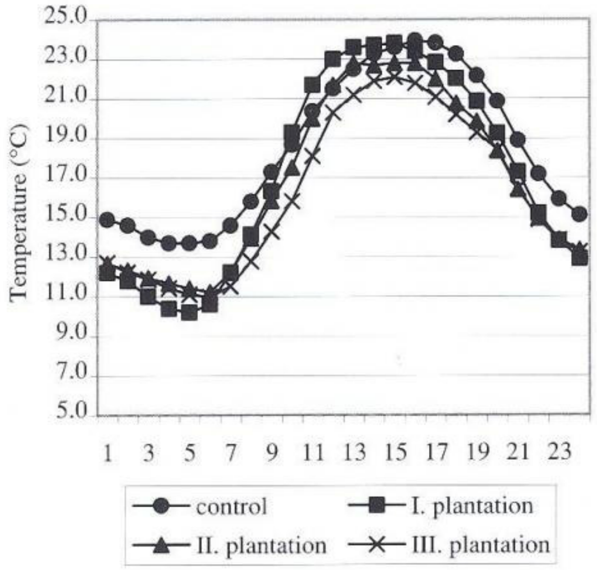

Figure 1 Daily distribution of temperature above the crown during the vegetation period (Derecske–2004)

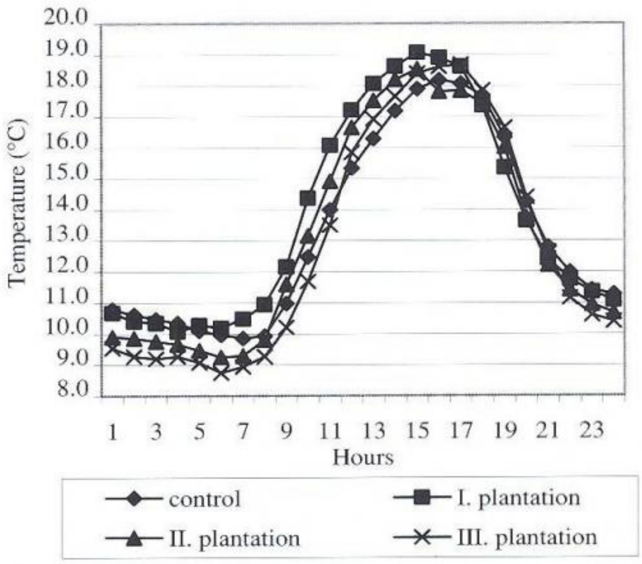

Figure 3 Daily distribution of temperature in the crown area during the vegetation period (Derecske–2004)

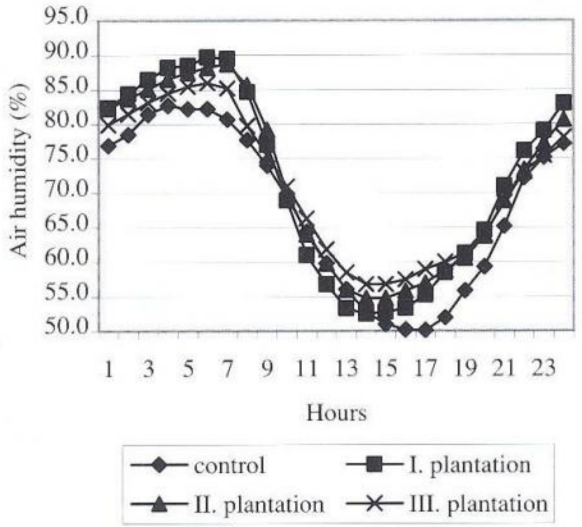

Figure 2 Daily distribution of air humidity above the crown during the vegetation period (Derecske–2004)

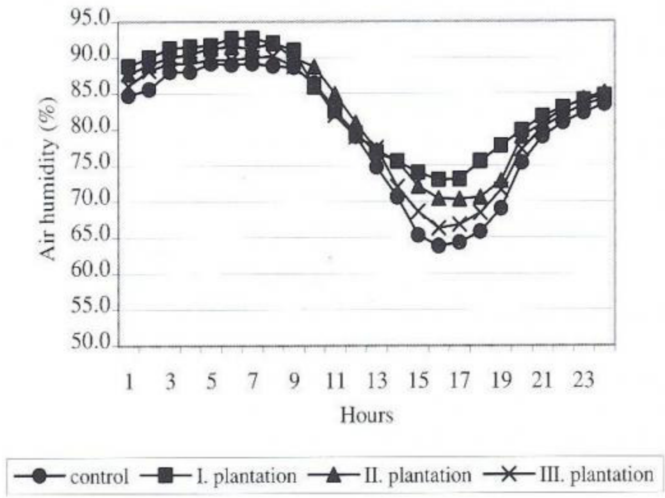

Figure 4 Daily distribution of air humidity in the crown area during the vegetation period (Derecske-2004)

Leafage / crown area

The heat shortage of the early morning and evening hours is followed by heat surplus in the late morning hours. Heat surplus is in direct proportion to the tree's age, that is density, while the degree of heat shortage is in inverse relation with the age of canopy. In the younger trees the extent of emission is greater because of the smaller leafage and as a result of this, their leafage cools down more by the early morning hours (*Figure 3*). Heat surplus in case of older, denser trees is 1.8–2.0°C, while heat shortage did not reach 1–1.5 °C even in case of thinner trees.

In the leafage, almost all day, relative humidity shows a higher value in the canopy areas compared to the out of canopy areas (*Figure 4*). Higher humidity condition in the crown area appears as a result of the combined effects of foliage transpiration, weaker displacement of air and surface evaporation. In the late morning hours, the start of convection decreases the heat surplus of the trees, which means that the difference in humidity becomes equal in the canopy and out of canopy areas. Owing to the intense evaporation in the evening and afternoon hours, leafage's air fulness starts to increase significantly again. The daily relative humidity amplitude of canopy areas changes in inverse ratio to the increase of canopy density. The daily humidity oscillation of denser canopies reaches 20–25%, while this value reaches 28–30% in case of thicker trees. The relative humidity differences in case of different aged and dense canopies reached 10% compared to out of stock area in the afternoon hours, while in night hours 4-5% differences are characteristic.

Trunk area

The trunk area of trees is cooler in the daily hours than its environment. Foliage absorbs a significant amount of solar

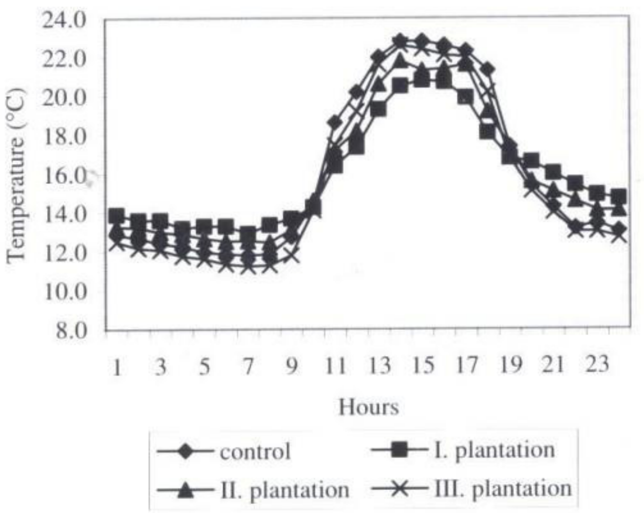

Figure 5. Daily distribution of temperature in the trunk area during the vegetation period (Derecske–2004)

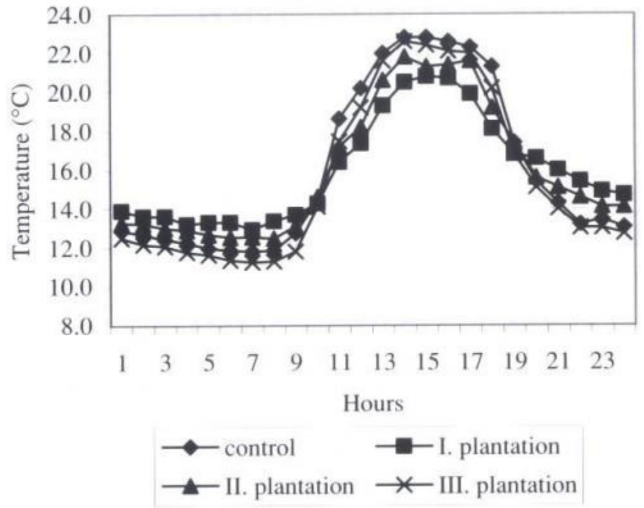

Figure 6. Daily distribution of air humidity in the trunk area during the vegetation period (Derecske–2004)

radiation, so the lower area of trees do not receive thermal energy from the direction of the surface, but from the direction of the leafage. As a result of this, from late afternoon hours older and thicker trees with more leafage and reception area become warmer than their environment. Night heat surplus can mainly be observed in case of older trees. Thinner trees can be colder than their environment (*Figure 5*).

Daily hours' heat shortage can reach 2–2.5 °C in case of older trees, while in night hours trunk area is 1–1.5 °C warmer than the out of canopy area. In case of thinner trees, heat shortage reaches 0.5–0.7 °C in night hours, since smaller leaf area reduces long-wave emission to a smaller extent.

Throughout the day, the relative humidity of trees' trunk area is higher than the value that can be measured in the out of canopy area (*Figure 6*). In the night hours in case of younger trees 6–5–6% higher relative moisture content values could be experienced. This can be explained by the fact that in the trees trunk area is the coldest because emmission is the highest here. On a reagular basis, lower temperature usually results in higher relative moisture content values. Older trees' relative moisture content surplus experienced in daily hours reaches 10% in the afternoon hours.

On windier days the differences in the values characteristic to canopy and out of canopy areas decrease by 30–40% compared to the values characteristic to days free from wind. Especially the relative humidity values show more significant change owing to the increase of wind speed. The differences in flows characteristic to line direction and vertical direction show 20–30% change as a result of different current direction.

Summary, conclusions

Temperature and humidity values characteristic to the range of fruit trees characteristically differ from the values characteristic to areas outside the range of fruit trees. The experienced differences are more significant in cases of small wind speed. This time the size of leafage, position, thickness and vertical volume distribution of foliage determine the meteorological elements' value characteristic to the range of fruit trees and their daily occurrence. The daily heat surplus of crown area is due to the fact that leaves absorb solar radiation, and as a result of this they intensely warm up.

At night hours the long-wave emission from the leaves' surface is almost undisturbed, so leafage cools down more than the surrounding area. Due to the daily hours' intense transpiration, higher relative moisture content can be measured in the leafage than in the area out of canopy. Humidity surplus remains in the night hours too, as a result of the foilage's vertical water vapour braking effect. Water diffusion coming from the directon of trunk area brings significant amount of water vapor to the leafage.

This means favourable terms for fingus and other plant pathogens to spread. In windless situations, the risk of plant contamination can be expected in canopy areas.

References

Anda, A. (1993): Surface temperature as an important parameter of plant stands. *Időjárás.* 97: 259–267

Berényi, D. (1952): A különböző sűrűségű őszi rozsvetések állományéghajlata. Debreceni Mg. Kísérleti Int. Évkönyve. 107–140.

Berényi, D. (1953): A vetéssorok égtáji irányításának hatása a mezőgazdasági növények állományklímájára. MTA Műszaki Tud. Oszt. Közl. 10. (3–4): 651–666

Bognár, K. & Kozma, F. (1961): Együttes szőlő-gyümölcstermesztés mikrometeorológiai vizsgálatáról. *Időjárás.* (6): 366–369.

Csapó, P. (1984): Szőlőültetvények téli fagykárának becslése. *Légkör.* (1): 19–21.

Csöbönyei, I. & Stollár, A. (1969): Az alma rügyfakadása és a rügyfakadás-virágzás fenofázis összefüggése a léghőmérséklettel. Kísérletügyi Közlemények. *Kertészet.* (1–3): 19–23.

Dunkel, Z. & Kozma, F. (1981): A szőlő téli kritikus hőmérsékleti értékeinek területi eloszlása és gyakorisága Magyarországon. *Légkör.* (2): 13–15.

Dunkel, Z., Kozma, F. & Major, Gy. (1981): Szőlőültetvényeink hőmérséklet- és sugárzás-ellátottsága a vegetációs időszakban. *Időjárás.* (4): 226–234.

Gonda, I. (1999): Az alma nyári metszésének hatásai. *Kertgazdaság.* 31 (2): 132–133.

Hunkár, M. & Bacsi, Zs. (1993): Kísérletek talaj–növény–időjárás modellekkel. *Meteorológia és Növénytermesztés.* 59–65.

Justyák, J. (1957): A paradicsom állományklíma vizsgálatának 5 éves eredményei. KLTE Met. Int. Tud. Közl. 3: 42. p.

Justyák, J. (1960): A művelési módok hatása a szőlő állományklímájára Tokaly-Hegyalján. Kandidátusi értekezés.

Kocsis, L. & Ligetvári, F. (1992): Előkészületek a Scheduler növényi stresszmérő készülék adaptációjára. *Magyar Szőlő- és Borgazdaság 2:* 5–8.

Lakatos, L. (2002): Állományklíma vizsgálatok almaültetvényben. Innováció, a tudomány és a gyakorlat egysége az ezredforduló agráriumában. Kertészet. Debrecen. 12–22.

Nyujtó, F. (1965): Gyümölcstermesztés és agrometeorológia az Alföldön. *Kertészet és Szőlészet.* (15): 8–9.

Pásztor, K. & Szabó, T. (1990): Növényállományok felszínhőmérsékletének kapcsolata a meteorológia tényezőkkel. *Időjárás.* 94: 4. p.

Stollár, A. & Zárbok, Zs. (1981): A gyümölcsök optimális termőhelyének elemzése hőmérsékleti adottságok alapján. *Légkör.* (3): 15–17.

Szász, G. (1956): A talajkülönbségek hatása az őszi árpa állományéghajlatára. *Agrokémia és Talajtan.* 5: 471–484.

Szász, G. (1961): Makro- és mikroklimatikus hatások a köszméte bogyók növekedésére és beltartalmára. *Időjárás.* (5): 279–288.

Tőkei, L., Gránási, T., Ligetvári, F. & Bulátkó, F. (1995): A növényi felszínhőmérséklet vizsgálata almaültetvényben. *Új Kertgazdaság.* 3: 18–24.

Tőkei, L. & Dunkel, Z. (2004): Investigation of crop canopy temperature in apple orchards. Physics and chemistry of the Earth. Published by Elsevier Ltd.