Acta Universitatis Sapientiae
Agriculture and Environment, **3**, (2011) 102–109

Spatial differences of night temperature in hilly regions and its horticultural importance

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Manuscript received April 25, 2011; revised May 24, 2011; accepted May 25, 2011

Abstract. In the Carpathian Basin freezing injury is one of the main yield limiting factors in fruit production. In our research the microclimatic differences of night temperature values were studied. On the northern side of Bükk Mountains, at two nearby (app. 1 km distance) locations, parallel temperature measurements were conducted from 17th April until 4th December 2010 (HOBO UA-002 logger). The measuring points represent the fruit gardens located in valleys (260 m a.s.l) and on slopes with medium cold air drainage (330 m a.s.l), respectively.

The critical frost events occur mainly (in the vegetation period almost exclusively) at clear, calm nights. In this type of weather the valley is generally 3-5°C colder than the slope position 70 m above it. These values hint to the enormous importance of site selection of orchards which is probably the simplest and most effective way to reduce frost risk.

Keywords: minimum temperature, frost risk, microclimate, orchard, topography, site selection

1 Introduction

The importance of low temperature is well known in horticulture. In the Carpathian Basin – similarly to many temperate regions – freezing injury is one of the main yield limiting factors in fruit production Most species are likely to suffer a serious loss due to spring frosts. One frost event is able to completely destroy the yield in some orchards, caused by the irreversible injury of reproductive organs. The losses can occur widespread in the country, or sometimes concentrated only to smaller regions. The yield-loss of particular species exceeds 50% on country-level in some years.

The autumn and winter frosts can also limit the production of some species (cultivars). In cold and temperate climates, low winter temperatures can damage the xylem, bark, roots and buds perhaps resulting the death of the trees. This limits the areal distribution of a particular crop relative clearly. However, the fruit trees that are tolerant to low winter temperature, may be very sensitive to spring frost injury [10].

The climate change probably will not reduce these risks, especially because of increasing temperature anomalies. Though, the forecasted milder winters and early springs may enhance the frost risk effecting the buds, flowers and developing fruits, because of the earlier beginning of the vegetation period [4].

Breeding of new cultivars for frost hardiness could be a possible way to handle this problem. However, these efforts are only slightly effective in reducing frost injury [10].

Different ways of frost protection are widely used in fruit growing [6, 9]. The methods show large differences in effectiveness and in costs. Generally, establishing and operating an effective protection system can take a significant part of the total costs of fruit production. Micrometeorological studies of frost events can help to develop the most suitable protection practices [11].

Low minimum temperature (different degree of frost) affects the production of most species of vegetables, as well. In this case there is an extra tool in hands of growers to reduce the risk of damage. They can minimize the damage by choosing proper sowing date [5].

The critical frost events occur mainly (in the vegetation period almost exclusively) at clear, calm nights. In this weather type the cold air layer developing due to longwave outgoing radiation of surfaces “flows down” according to the local terrain. Cold air accumulates in valleys, on low plains and in basins, while places with good cold air drainage remain relatively mild [2].

The nighttime temperature distribution in hilly areas was studied and modeled usually in case of forest or heterogeneous land cover [1, 8, 12]. Huge differences in temperature (5-10°C) can develop even within short distances (¡100 m) in case of some terrain forms [3, 7]. Against the different vegetation type, these results highlight the importance of microclimate. The microclimatic characteristics are usually considered in site selection of orchards, but until now usually without quantitative information about temperature differences or about risk levels.

In our research we compared the nighttime thermal characteristics of two sites close to each other, representing orchards in an "average good" and in an "average unfavorable" position. Differences in daily minimum values and in courses of night temperature were analyzed according to weather type.

2 Material and methods

On the northern side of Bükk Mountains in Hungary (48°09'N, 20°30'E), at two nearby (app. 1 km distance) locations, parallel temperature measurements were conducted from 17th April until 4th December 2010. Temperature loggers (HOBO UA-002, accuracy within 0.2°C according to our tests), were placed in shelter at 2 m height, and installed to logging interval of 10 minutes. The measuring points represent the fruit gardens located in valleys (260 m a.s.l) and on slopes with medium cold air drainage (330 m a.s.l), respectively.

Hourly data of the nearest (20 km) synoptic meteorological station of the Hungarian Meteorological Service, Miskolc were used to categorize the nighttime weather. Data of temperature, air humidity, wind, cloudiness and actual weather event were read out from archived synop reports (www.ogimet.com).

The nights were chosen into weather type "calm-clear" when the minimum of temperature was developed typically under the following circumstances:

- cloudiness $\leq 2/8$($\leq 4/8$ in case of Cirrus clouds),
- wind speed ≤ 3 m/s.

As opposite, also the overcast, rainy night were studied, when the longwave radiation plays no role in forming the temperature distribution. The minimum temperature of each day (from 8 PM till 8 AM), and their differences between the two locations were calculated using Excel. The nighttime courses of temperature were displayed and compared using Hoboware program and Excel.

3 Results and discussion

In the study period 69 nights were clear and calm, according to our classification. In every occasion the minimum temperature in the valley was at least 2°C lower than that registered at the upper station. The difference was in average 3.7°C.

It was not possible to detect seasonal variation, because it was hidden by the specific, usually moist weather of this year. Instead of this we found that the differences are smaller when air humidity is higher (which is in connection with previous precipitation).

Distribution of the differences shows that in the "clear and calm" weather type the valley is generally 3-5°C colder than the slope position 70 m above it. The temperature difference was in this interval in 55 from 69 cases (80%), and it showed a maximal probability between 3.5 and 3.9°C (Figure 1).

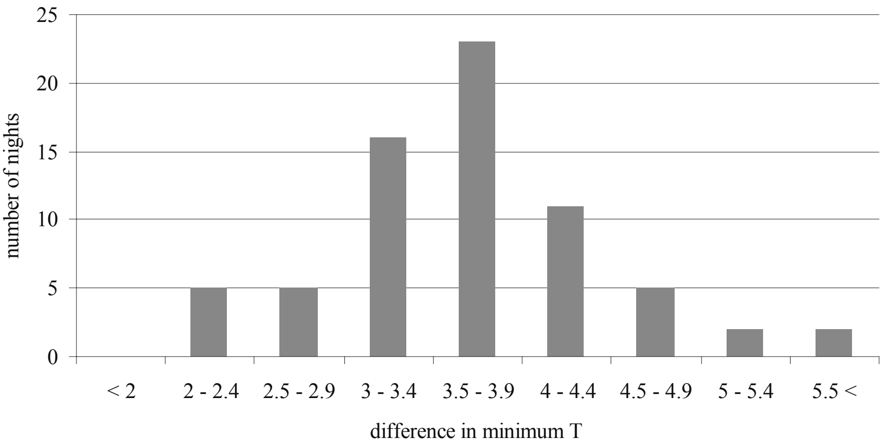

Figure 1: Distribution of the differences between the minimum temperature measured at the station on the slope and in the valley, at calm-clear nights

The largest difference in minimum temperature reached 7.3°C at an April night. This could occur after/at the end of a cool period, when warmer air in the higher air layers helped develop a very strong inversion. The dry air (low value of dewpoint) made an undisturbed cooling possible at the valley.

It was found that at overcast nights with precipitation the temperature decreases with elevation nearly according to the wet adiabatic gradient of 0.6°C/100 m. So, the differences are very small compared to the differences in inversion of clear-calm nights. Figure 2 shows that the differences are limited to a very narrow interval.

This stability in differences is valid not only for the minimum values, but also for any time of the night. During rainy nights the temperatures in the valley and on the slope run almost parallel (Figure 3).

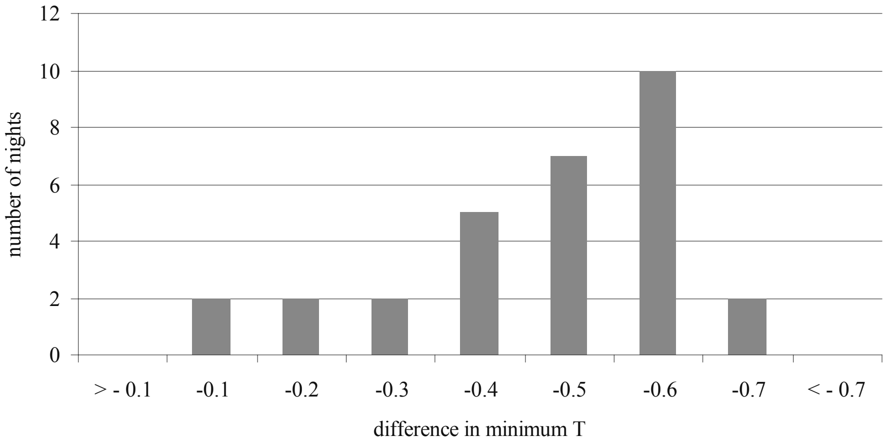

Figure 2: Distribution of the differences between the minimum temperature measured at the station on the slope and in the valley, at rainy nights

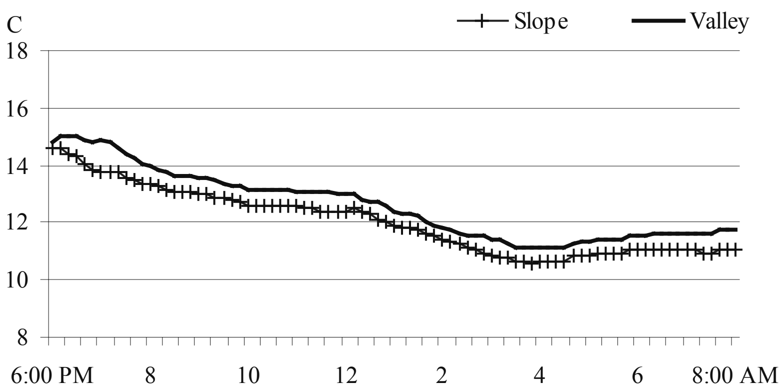

Figure 3: The course of temperature at a rainy night (31th May, 2010) at the station in the valley (260 m) and on the slope (330 m)

At calm-clear nights the course of the temperature in the valley differs from the course of the temperature on the slope. Typically, the temperature difference increases rapidly in the first part of the night (the valley is colder). The air cools down near to its minimum relatively early in the valley (compared to the slope). In some cases the temperature on the slope remains relatively high except a short period around the time of minimum (Figure 4).

Thus in a significant part of the night the temperature difference between the two locations can be larger than the differences in minimum values. This phenomenon also has a horticultural importance.

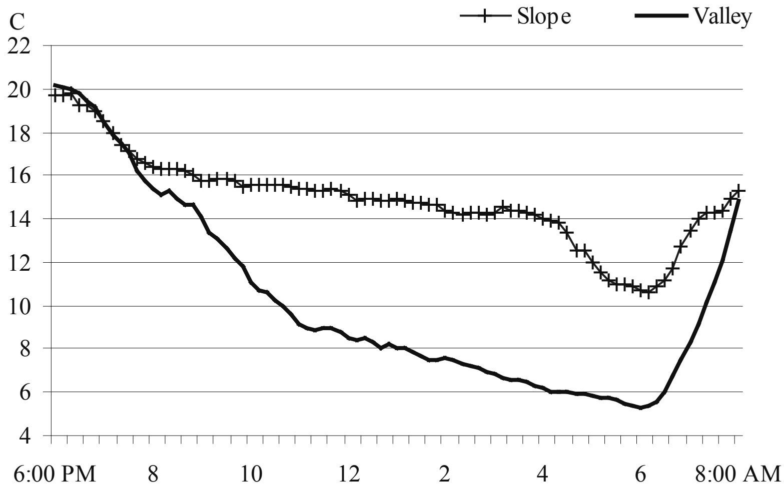

Figure 4: The course of temperature at a calm-clear night (April 24-25, 2010) at the station in the valley (260 m) and on the slope (330 m)

Figure 5 shows the temperature 22nd April, 2010. In the valley the minimum reached nearly -3°C and temperature was subzero for about 6 hours. At the same time the slope with cold air drainage remained frost-free. In such situations high variations in frost injury can evolve according to the local topography.

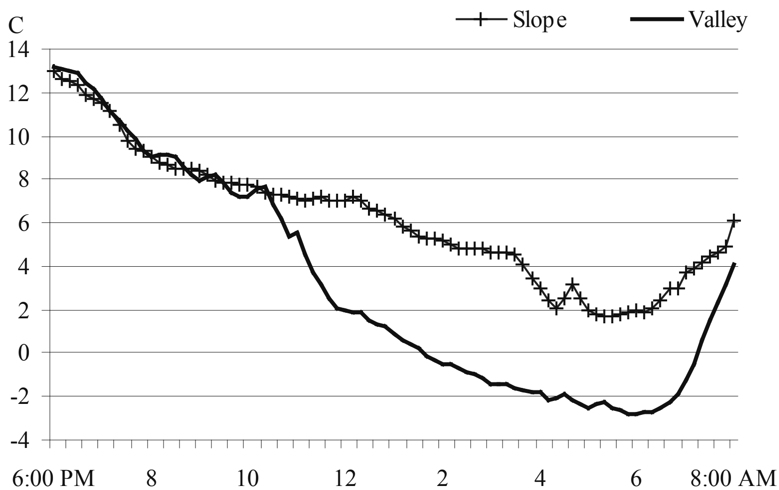

Figure 5: The course of temperature at a calm-clear night (April 22-23, 2010) at the station in the valley (260 m) and on the slope (330 m)

4 Conclusion

Our results hint to the enormous importance of the site selection of orchards. Favorable locations can be warmer by near 5°C at critical cold nights. This difference can mean an advance of nearly one month in time of the last damaging frost. Probably, the site selection based on detailed microclimatic studies is the simplest and most effective way to reduce frost risk. The cooperation of meteorologists and horticultural engineers can give the best results both in the research and the operative phase of the work.

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