MICROCLIMATIC DIFFERENCES IN FRUIT ZONE OF VINEYARDS ON DIFFERENT ELEVATIONS OF 'NAGY-EGED HILL' IN EGER WINE REGION, HUNGARY

Borbála BÁLO[1*], Márta LADÁNYI[2], Nikoletta SZOBONYA[1], Péter BODOR[1], Tamás DEÁK, György Dénes BISZTRAY[1]

[1]*Department of Viticulture, Szent István University, Budapest, Hungary*
[2]*Department of Biometrics and Agricultural Informatics, Szent István University,Budapest, Hungary*
**Corresponding author: Bálo. E-mail: balo.borbala@kertk.szie.hu*

Abstract

The Bull's Blood of Eger (*'Egri Bikavér'*) is one of the most reputed red wines in Hungary and abroad, produced in the Northeastern part of the country. It is known as a ruby blended, full bodied red wine with fruity and aged character. *Vitis vinifera L.* Kékfrankos (Blaufränkisch) is the base component of the *'Egri Bikavér'*, beside it is the most abundant red grape cultivar of the region and of Hungary. It is grown in many vineyards along the wine region resulting in different wine quality and style depending on slope, elevation, aspect, soil and microclimatic conditions.

Several attempts using GIS technics have been made recently to characterize the most important growing sites in the wine region concerning topographical, soil and climatic conditions. Data of automatic meteorological weather stations located in the vineyards, E-OBS gridded database and the PRECIS regional climate model was also used to better understand the suitability of the vineyards for Kékfrankos quality wine production.

In the present study, we described with a fine scale measurement the fruit zone microclimate (temperature, relative humidity) in three vineyards differing in their elevation on the emblematic 'Nagy-Eged hill with EasyLog EL USB-2+ temperature and humidity sensors (Lascar Electronics, UK). The elevation of Nagy-Eged hill lower part [NEL] is *294 m*, Nagy-Eged hill middle [NEM] is *332 m* and Nagy-Eged hill top [NET] is *482 m* above sea level. Measurements were taken in 2015 July-October. Mathematical calculation of multiple comparison, i.e. Marascuillo's procedure was used to distinguish microclimatic differences among different elevations. Day and night time data were separately analyzed.

Concerning the temperature data of Nagy-Eged Hill, we may suppose that the effect of a thermal belt was the principal factor influencing fruit zone temperature, since the warmest area (especially at night) was the middle part of the hill, although the upper part is far steeper, therefore it could receive more solar radiant heat than the others. Soil is richer in gravels, stones on the top of the hill and in the middle part, but the re-radiation heating effect did not exceed that of thermal belt.

Due to the moving of cooler air masses towards the lower part of a valley and the lower wind speed, the air surrounding the vines gets more humid in most part of the growing season. The advantage of dryer air conditions in the middle and top positions of the hill may be benefited by using environmental friendly cultivation technology with less pesticides.

Climate change is a challenge at the Nagy-Eged Hill not only for temperature increase and water shortage, but also for heavy, irregular precipitation that results in serious erosion problem.

Key-words: terroir, slope, fruit zone, temperature, humidity, thermal belt

1 INTRODUCTION

Lucius Columella in the first century stated that wine quality depends mostly on the temperature around the vine (Hancock, 2005). Detailed studies of Amerine and Winkler (1944) described the beneficial effect of heat on grape ripening, further Winkler et al. (1974), Kliewer and Lider (1968) emphasized the positive effect of grater day/night temperature difference. Most of their studies and experimental work were done in the Napa Valley (located around 38^o N latitudes and 122 ^{o} W longitudes, 35-100 m a.s.l.). Ripening process heat demand of the cultivars and the underlying physiological mechanisms were explained accordingly. Later different climatic indices were elaborated to characterize the macro and mezo climate of a given wine growing region (Winkler et al., 1974, Branas, 1974, Huglin, 1978, Fregoni et al., 2002; Gladstone, 1992, Tonietto and Carbonneau, 2004). Meteorological data, upon the calculations were performed, had been obtained from meteorological weather stations (MWS) handled manually or automated later. The data accuracy of a given region depended on the number of stations, sometimes not taking into consideration the geographical heterogeneity, as altered slope and aspect of a smaller area. Hancock (2005), Hugett (2006), Tomasi et al. (2012), Matese et al. (2014) highlighted a number of factors that may affect the microclimate of vineyards with very similar latitude, but differing in geological, soil conditions, elevation. Different new meteorological data sources are freely available lately, as E-OBS gridded database (Sámson et al., 2014), and others, that facilitate to complete missing data measured with MWS, however, the resolution is not adequate in some cases for fine scale characterization of a vineyard. New research approaches, weather and climate models i.e. Weather Research and Forecasting (WRF) model allow to better understand climate variability at high spatial and temporal resolution (1 km or higher recorded hourly or more frequently, respectively) in the vineyards (Sturman et al. 2016). CARPATCLIM (http://www.carpatclim-eu.org/pages/home/) is a new data source for East-European countries with a 0.1 x 0.1 degree resolution.

The Bull's Blood of Eger (*'Egri Bikavér'*) is one of the most reputed red wines in Hungary and abroad, produced in the Northeastern part of the country. It is known as a ruby blended, full bodied red wine with fruity and aged character. *Vitis vinifera L.* Kékfrankos (Blaufränkisch) is the base component of the *'Egri Bikavér',* beside it is the most abundant red grape cultivar of the region and of Hungary. It is grown in many vineyards along the Eger wine region resulting in different wine quality and style depending on slope, elevation, aspect, soil and microclimatic conditions. Several attempts using GIS technics have been made recently (Bálo et al., 2014) to characterize the most important growing sites in the wine region concerning topographical, soil and climatic conditions. Data of automatic meteorological weather stations located in the vineyards, E-OBS gridded database and the PRECIS regional climate model was also used to better understand the suitability of the vineyards for Kékfrankos quality wine production.

In the present study, we described the fruit zone's microclimate (temperature, relative humidity) with a fine scale measurement in three vineyards differing in their elevation on the emblematic 'Nagy-Eged-hegy' (hill) producing premium wine quality, but differing in wine style along the slope. The study was carried out in the 2015 growing season.

2 MATERIALS AND METHODS

The location of the measurements was in the Eger wine district (Northeastern part of Hungary). The topographical position and the ortho photo of the vineyards is shown in Figure 1 and Figure 2.
The position of the vineyards are as follows (Northern latitude; Eastern longitude; elevation above sea level):

Nagy-Eged Hill Lower part (NEL)	47°55'10'' N lat.; 20°25'12''E long.; 294 m a.s.l.
Nagy-Eged Hill Middle part (NEM)	47°55'18'' N lat.; 20°25'06''E long.; 332 m a.s.l.
Nagy-Eged Hill Top part (NET)	47°55'36'' N lat.; 20°25'03''E long.; 482 m a.s.l.

The bedrock and soil types of the examined plots are as follows:
NET Upper Eocene Szépvölgy Limestone Fm., Rendzina soil, smaller and bigger chalk stones, gravels on surface, 20-35% slope inclination.
NEM Upper Oligocene Buda marl, loamy, sandy-loamy soil with chalk stones, gravels 17-25 % inclination.
NEL Upper Oligocene Buda marl, clay loamy, loamy soil with Holocene alluvial deposit 12-17 %.
The fertile soil layer on the lower part of the hill (NEL) is ca. 150-180 cm, in the middle part (NEM) it is around 100-150 cm and on the top (NET) 30-45 cm (Dobos et al. 2014).
Vines of *Vitis vinifera* L. Kékfrankos plants were vertically shoot positioned, the rows had North-East to South-West orientation with 3 m x 1.2 m row and vine spacing.

For fine scale microclimatic measurements, EasyLog EL USB-2+ temperature and humidity sensors (Lascar Electronics, UK) were mounted with four repetitions in the fruit zone of the vines. The measurements were gathered in three time intervals: 6th of June – 21st of July; 21st of July – 26th of August and 26th of August – 2nd of October. The three time intervals are simply explained with battery changes of the sensors. We split all the three time interval data sets into two and defined the records as '*day*' (7 am. to 7 pm.) and '*night*' (7 pm. to 7 am.). Temperature [°C] and relative humidity [%] were recorded every five minutes. The means (m) and variances (var) of the four values recorded by the four sensors installed in each of the three vineyards were calculated. We said that a mean record (m) of a point of time measured in the site i (denoted with m_i) is higher than the one measured in site j (denoted with m_j) if m_i-m_i > var_i+var_j where var_i and var_j denote the variances of the observations at the same time point in site i and site j (i and j denote NEL, NEM or NET such that $i\neq j$). In case the difference between two means were less than var_i+var_j, we considered the two values as similar. In this way, we prepared the pairwise comparisons of the temperature and humidity parameter values measured at the same time in different vineyards i and j. We calculated the relative frequencies p_{i+}, p_{i-} and p_{i0} of "m_i is higher than m_j", "m_i is lower than m_j" and "m_i is similar to m_j", respectively, and compared these estimated probabilities by Marascuillo's procedure (Marascuillo and McSweeney, 1967).

3 RESULTS AND DISCUSSION

Summarizing the fruit zone temperature data, in the first interval (Figure 3) there were not significant differences among the growing sites of different elevation during day time (NEL, NEM and NET). The night time values proved to be significantly higher at the middle part of the Nagy-Eged hill (NEM). In the second interval (Figure

4), day time values showed similar tendencies as in the first one. However, at night NEM was again the warmest, NEL and NET were cooler, but not differing from each other significantly. In the third interval (Figure 5) during the day the lower and middle part were significantly warmer than the top. At night, each of the three elevation were significantly different from each other: the warmest fruit zone was again in the middle part, lower temperature values were detected at the lower part of the hill and the coolest was the hill top in the fruit zone of the vines (Table 1).

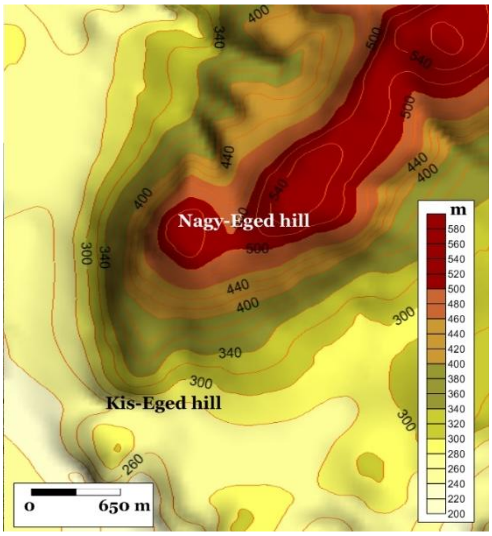

Figure 1: The topographical position of Nagy-Eged Hill (Dobos et al., 2014).

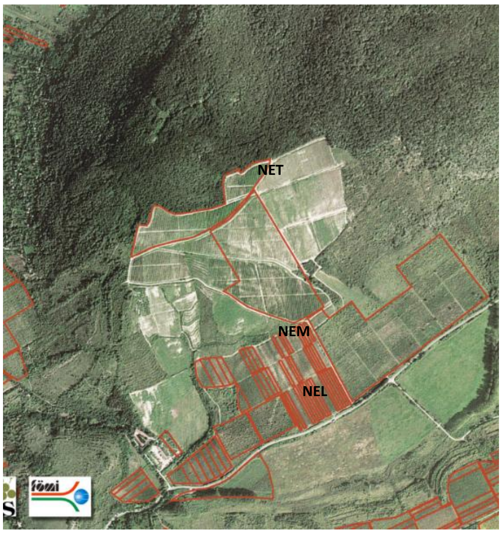

Figure 2: Ortho photo of the three examined growing sites. NEL, NEM and NET indicate the lowest, the middle and the top position of the vineyards (separately).

Tomasi et al. (2012) cite a general geographical law, namely temperature drops approximately 0.6 °C with every 100 m elevation. However, there are other factors influencing the heat distribution along a hill slope. According to Joshino (1984) and Hancock (2005), a thermal belt (i.e. an intermediate zone) is developing in the middle of a slope due to the moving of cold air towards the lower part of a hill and the wind movement. The location of a belt is higher in winter and lower in summer. At lower latitude (in warmer wine growing regions) it may not have an advantage as ripening processes are concerned, but closer to the Northern border of vine cultivation it could have a beneficial effect on sugar accumulation and the amount and composition of polyphenols in the ripening phase. The re-radiation of heat from the ground is another factor influencing fruit zone temperature. The albedo of lighter sand is higher, than that of damp clay soil. Stones and gravels on the surface of cultivated soil may also reflect absorbed heat at night (dark colored reflect more). At a latitude higher than 47^0 (Eger, Tokaj wine regions of Hungary; Piesport in Mittelmosel or Rheingau in Germany; Chateauneuf-du-Pape in France), pebbles have beneficial effect while heating the microclimate around the vine, close to the ground. Slope angle also effects the temperature close to the ground. The steeper the slope is, the more radiant heat will receive the vine plant and the fruit zone (Hancock, 2005; Hugget, 2006).

Concerning our temperature data of Nagy-Eged Hill, we may suppose that the effect of thermal belt was the principal factor influencing fruit zone temperature, since the warmest area (especially at night) was the middle part of the hill (NEM), although the upper part (NET) is far steeper (20-35 %), than the others and soil is richer in gravels, stones on the top of the hill (NET) and NEM. Another very important question in a terroir is, how steep should be a slope to be planted with vine rows parallel to the slope and where is the limit where the growers should use perpendicular rows or build terraces. On the Nagy-Eged Hill, the top part is subjected to serious erosion problem (due also to soil properties). The climate change resulting partly in heavy rainfalls during a short time period is a new challenge for the growers.

The day and night relative humidity data of the fruit zones also followed their own patterns (Table 2). In the first observation interval (Figure 6), the highest humidity during daytime was measured in the middle part of the hill (NEM), and the lowest on the top, however, the differences were not significant. At night, the lower part was considerably more humid. This was the case in the second interval as well (Figure 7). Towards the autumn (Figure 8), in the ripening phase, the least humid fruit zone was the middle part (NEM). Due to the moving cooler air masses towards the lower part of a valley and the lower wind speed, the air surrounding the vines gets more humid in most part of the growing season. The advantage of dryer air conditions in the middle and top positions of the hill may be benefited by using more environmental friendly cultivation technology with less pesticides.

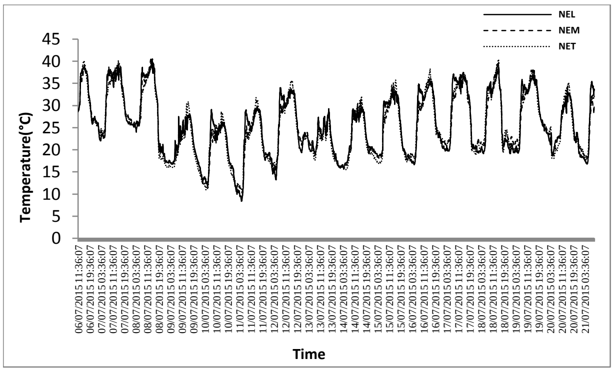

Figure 3: Differences in day and night temperature data in the fruit zone at different elevations of Nagy-Eged Hill (06.07.2015-21.07.2015).

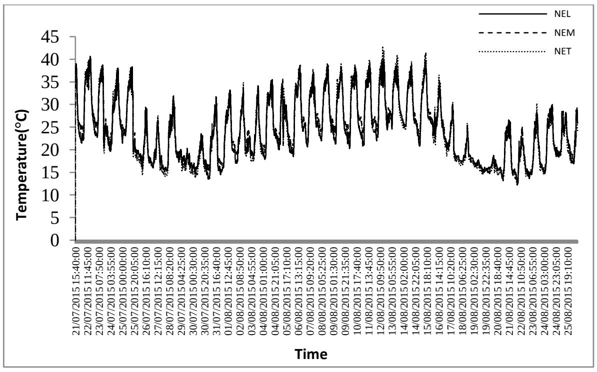

Figure 4: Differences in day and night temperature data in the fruit zone at different elevations of Nagy-Eged Hill (21.07.2015-26.08.2015).

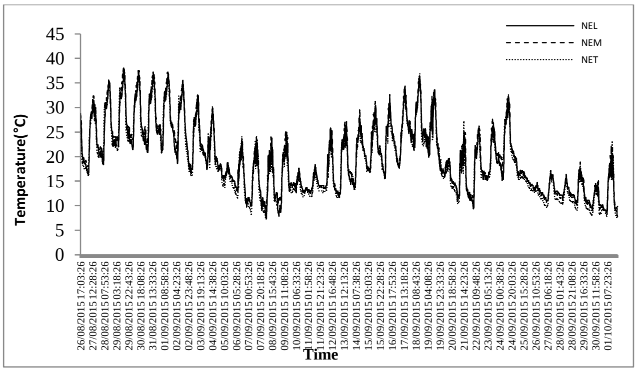

Figure 5: Differences in day and night temperature data in the fruit zone at different elevations of Nagy-Eged Hill (26.08.2015-01.10.2015).

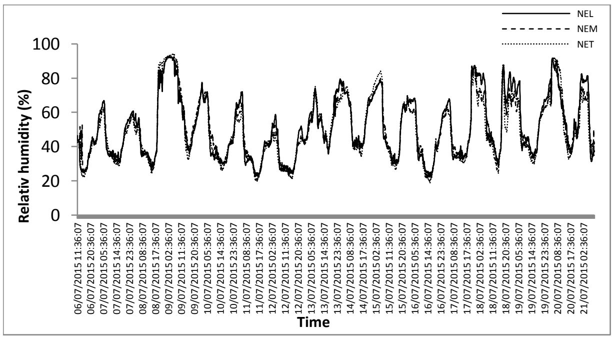

Figure 6: Differences in day and night relative humidity data in the fruit zone at different elevations of Nagy-Eged Hill (06.07.2015-21.07.2015).

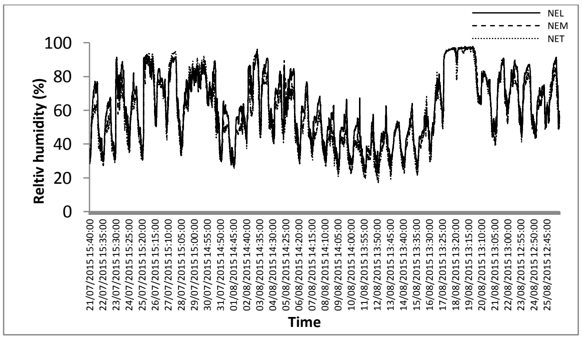

Figure 7: Differences in day and night relative humidity data in the fruit zone at different elevations of Nagy-Eged Hill (21.07.2015-26.08.2015).

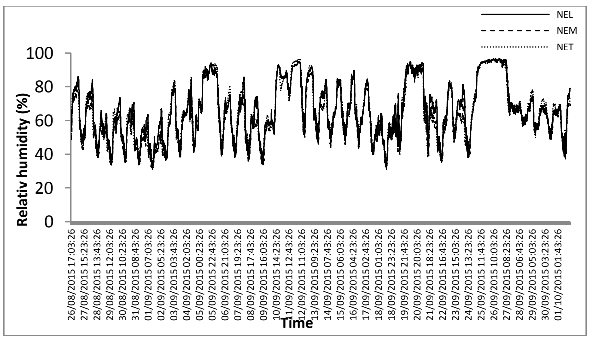

Figure 8: Differences in day and night relative humidity data in the fruit zone at different elevations of Nagy-Eged Hill (26.08.2015-01.10.2015).

Table 1. Temperature means [°C] and standard deviations in three time intervals in three vineyards. Different letters are for significantly different values in comparison of the vineyards separated by Marascuillo's procedure (p<0.05). Significantly higher night values in vineyard NEM are in boldface.

Time interval			Vineyard					
			NEL		NEM		NET	
6th of June – 21st of July	Day	Mean	30.7	a	30.1	a	30.1	a
		StDev	5.0		5.4		5.5	
	Night	Mean	20.5	b	**20.9**	**c**	20.4	a
		StDev	4.3		4.2		4.3	
21st of July – 26th of Aug.	Day	Mean	27.6	a	27.4	a	27.6	a
		StDev	6.7		6.6		7.4	
	Night	Mean	20.7	a	**21.5**	**b**	20.8	a
		StDev	4.1		4.5		4.5	
26th of Aug. – 2nd of Oct.	Day	Mean	20.7	b	21.5	b	20.8	a
		StDev	4.1		4.5		4.5	
	Night	Mean	16.9	b	**17.2**	**c**	16.4	a
		StDev	5.0		5.2		5.2	

Table 2. Relative humidity means [%] and standard deviations in three time intervals in three vineyards. Different letters are for significantly different values in comparison of the vineyards separated by Marascuillo's procedure (p<0.05). Significantly higher values are in boldface.

Time interval			Vineyard					
			NEL		NEM		NET	
6th of June – 21st of July	Day	Mean	40.1	a	41.4	a	39.5	a
		StDev	13.4		14.0		15.1	
	Night	Mean	**62.6**	b	60.4	a	59.7	a
		StDev	14.9		14.3		14.9	
21st of July – 26th of Aug.	Day	Mean	55.2	a	54.4	a	52.0	a
		StDev	19.2		19.8		21.3	
	Night	Mean	**70.2**	b	65.2	a	65.2	a
		StDev	16.3		17.6		18.1	
26th of Aug. – 2nd of Oct.	Day	Mean	60.5	a	58.8	a	59.6	a
		StDev	16.8		17.8		17.2	
	Night	Mean	**72.0**	b	69.5	a	**71.0**	b
		StDev	12.9		13.7		13.7	

4 CONCLUSION

Concerning our temperature data of Nagy-Eged Hill, we may suppose that the effect of a thermal belt was the principal factor influencing fruit zone temperature, since the warmest area (especially at night) was the middle part of the hill, although the upper part is far steeper, so it could receive more solar radiant heat than the others and soil is richer in gravels, stones on the top of the hill and in the middle part, but the re-radiation heating effect did not exceed that of thermal belt.

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