FINAL REPORT on the consortial project No113209 (main project)
with No 113223 and No. 113255, as co-projects (2015-2018) entitled:

Climatic conditions of grape and wine production in historical wine production regions of Northern Hungary

The project was planned to be performed by three research institutions. They were Eszterházy Károly College, Eger (EKF):, Károly Róbert College, Gyöngyös (KRF) with its Research Institute for Viticulture and Enology, located in Eger and , Research Institute for Viticulture and Enology, Tarcal (TSZBK). Though there were administrative changes during the 2015-2018 period, when the names of the units changed but the research was performed by the originally planned three institutions and by the originally planned researchers. One year prolongation was asked and received, so we worked for four years (2015-2018) instead of three (2015-2017).

In the Report below we follow the original for main points, but without going down to the sub-points, as it had been performed by the annual reports on the research in the years 2015, 2016 and 2017.

The main points of the research were:

I. Macro-scale analysis: plant – weather relationships
II. Effects of climate change and adaptation
III. Terroir-scale analysis: effect of weather and climate on plant development
IV. Integration of the terroir-results into the recommendations on adaptation to climate

I. Macro-scale analysis: plant – weather relationships

Must sugar concentration, titratable acidity and pH of Cabernet franc, Cabernet sauvignon, Bianca, Olaszrizling were also collected, processed and analysed at Eger, Kőlyuktető (1995-2015). Changes in berry sugar content of these three cultivars showed a similar trend. We can observe an increasing tendency of sugar level from the first examined vintage. In the case of titratable acidity we can see a reverse trend compared to sugar concentration. By this parameter we can observe a progressive decrease. Generally, during ripening the must acidity decreases, and the warm and sunny weather enhances this lowering. The level of pH also shows remarkable tendency. The pH varies opposed to the acidity. During ripening the level of pH increases, however the values of pH do not depend only on the level of titratable acidity. As a consequence we can state that the higher annual average temperatures resulted in higher levels of sugar and pH, and lower titratable acidity.

Viticultural regions for quality wine production are located in relatively narrow climatic niches that put them at greater risk from climate change than other broader acre crops. Our target area, the Matra Region is fairly close to the edge of optimal wine production concerning its climate conditions. Fifty year (1961-2010) wine and quality (natural sugar content, in weight % of must) data are analysed and compared to parallel climate variables in the Matra wine region. Two sets of station-based monthly temperature, sunshine duration and precipitation data, taken from two neighbouring stations, are used altogether in 132 combinations. In addition, daily grid-point data provided by the CarpatClim Project are used. By now it is clear that (1) wine amount is a year-by-year varying combination of natural productivity and man-made attempts to achieve better quality by thinning the grape clusters in spring. Therefore we separated a 30 years and a 20 years part breaking them by 1991. (2) wine quality, is in significant negative correlation with the annual precipitation and in positive correlation with temperature and sunshine duration. (3) Applying a wide combination of monthly data we obtain even higher significance according to t-tests from the station-based data, but it is difficult to select and optimum model from the many proper combinations just slightly differing in performance over the test sample. (4) The interpolated areal averages of the grid-point data promise good results, but their statistical analysis by using 5-day averages is just in its initial phase. It is clearly seen that June 5-day temperature strongly influences the sugar content in the Matra-region.

Figs 1 represents the wine amount and wine quality (expressed in must sugar content.

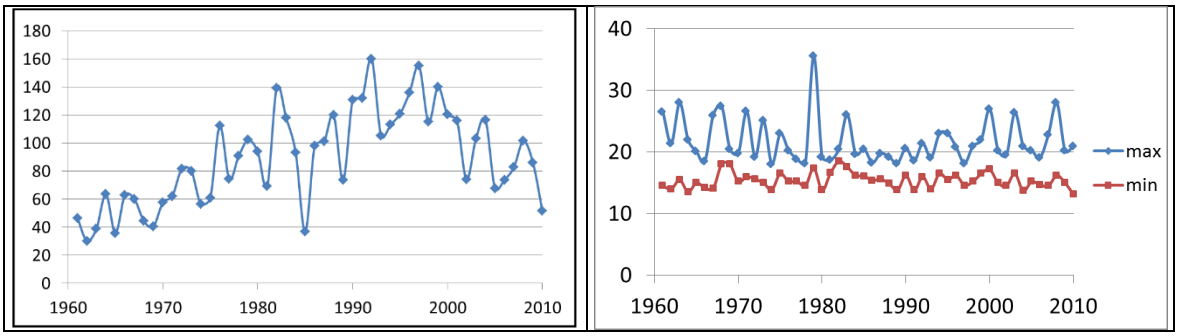

Fig. 2. Left: Evolution of grapevine quantities (q/ha) and Right: of must quality (0.01 kg sugar/1 kg must) in the Mátra region, as registered: maxima and minima of the given year are archived.

Using 126 combinations of monthly temperature sum, precipitation and sunshine duration, we obtain 126 potential independent variables. Surprisingly, the step-wise multi-regression procedure, that decides on explained variances according to F-test, selected two variables, only. They are the temperature sum of June and sunshine duration of the May-October period. If comparing the regression coefficients to the average values, one can establish considerable effect of both meteo-variables. Table 1. comprehends the most significant results of these computations.

Table 1. *The key variables explaining highest portion of variance in sugar content. The means are given to relate the regression coefficients. The mean must sugar degree was 18.3 for 1976-2006. The 95% significance threshold for the multi-correlation is 0.35.*

Key variable	Mean	Regression coefficient	Multicorrelation
Temperature sum June	571 °C	2,9 deg/100 °C	0.54
Sunshine duration May-Oct	1340 hours	0.7 deg/100 hours	0,62

We also performed an analysis of Tokaj wine quality and quantity data, similarly to that performed for the Matra wine production region. The first important results are as follows: (i) The wine quantity series is not homogenous, hence the simple search for climate effects performed for the whole period would be misleading. (ii) Having established homogenous periods, the latter 59 years exhibit mindful correlations between wine amount and some climate variables. (iii) There are no sequences in the wine quality series, hence it can be investigated for climate effects. (iv) In some months and climate variables there are mindful correlations.

In the Tokaj wine region we examined the plant reactions to the extremes. Thus, we were able to test the rot due to the humid summer of the year 2014, and the drought tolerance in the drought summer of 2015. The frequent rain, constantly humid environment helped the grey rot and sour rot appearance in 2014. It was a good possibility to examine the rotability of Furmint clones. Significant differences were found in the degree of rot at different clones of Furmint. The P.26 clones were far affected, while the T.8 / 7575 series clone was minimally infected. The T.85 clone proved to be the most rotable, which is the most widespread clone.

Drought symptoms in the vast majority of vines were experienced, where the wilking were the most common in summer. We couldn't find significant difference between the three rootstocks in terms of drought tolerance held on Furmint. Ruggeri 140 - FERCAL - Teleki 5C order of decreasing drought tolerance according to the literature, but our study does not confirm or deny it clearly, although most of the asymptomatic vines were on Teleki 5C rootstock. When drought tolerance of Furmint clones were tested with aggregate of the three rootstocks, it can be stated that the currently in production T.85, T.92 clones performed well, while most of them ahead of T.508, P.137, T.8 / 7575 P .133 clones had the best drought tolerance.

The Bois noir (BN) disease induced by 'Candidatus Phytoplasma solani' (CPs) is common in European vineyards. Its damage has not been fully investigated, especially with regards to wine attributes. The impact of BN on yield, berry composition and wine characteristics of Vitis vinifera L. cv. 'Chardonnay' was therefore comprehensively characterized in a 3-year field experiment in Hungary, Eger winegrowing region. Additionally, the bindweed-related tuf-b1 genotype was identified to be involved in the BN pathosystem in the experimental vineyard. Infection of CPs tuf-b1 genotype resulted in severe yield loss, the average decrease in number of bunches and total yield per vine was 56.7% and 68.4%, respectively. Analyses of wines produced from grapes of BN infected vines revealed decreased alcohol, epicatechin and iron contents; and increased organic acids, titratable acidity, catechin and calcium contents. Sensory evaluation of these wines confirmed unfavourable characteristics, i.e. higher acidity, bitterness, and usually pinkish discolouration. Negative impact on berry composition and wine quality were pronounced in the vintage with favourable weather conditions for grapevine production, whereas the negative effects of BN infection were less prominent, even masked, in the vintages with unfavourable weather (wet and cool). To reduce BN-caused damage, the need for improved preventative and curative measures for BN disease is highlighted.

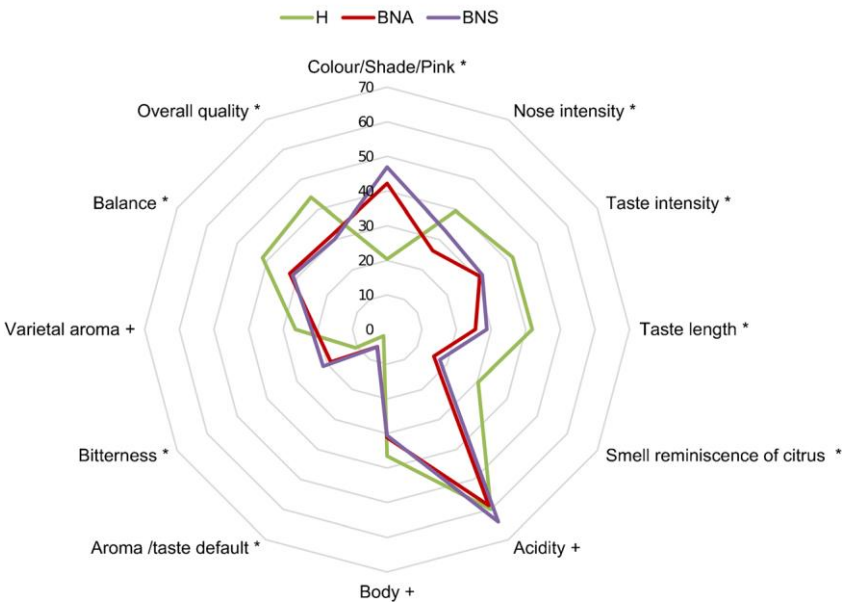

*Fig. 3. Wine profile analysis of year 2013. Legend: H: yield of healthy vines. BNA: yield of BN-affected vines. BNS: shrivelling bunches of BN-affected shoots. Asterisks: significant differences between H and BNA at values: * $P < 0.05$, + $P < 0.1$. Statistical analysis of BNS wines was not applicable*

*Fig. 4. Summary of parameters related to the decrease or increase in yield, must and wine quality caused by Bois noir disease in V. vinifera L. cv. 'Chardonnay'. Legend: Yield and must quality of 15 healthy and BN-affected vines have been analysed by two-way ANOVA. Wines of healthy and BN-affected plants have been analysed by the two-way MANOVA method, while the sensory analysis by the Mann-Whitney U test. The internal circle depicts the four groups of measured parameters: yield, must, wine and sensory analyses. Median circles in grey represent a logarithmic (log10) scale of average changes of BN-affected vine performance compared to those of healthy plants based on a multi-year average (%); red and blue columns refer to performance increases (+) and decreases (−), respectively. External circle: measured parameters showing significant differences (+P < 0.1, *P < 0.05, **P < 0.01, ***P < 0.001)*

Fungal disease resistant interspecific grape varieties are playing an important role as an alternative for organic wine production. Organic wines are demanded by numerous conscious consumers around the globe. They choose these kind of wines predominantly because of the absent of synthetic pesticides, fertilizers and sustainable agriculture. Resistant grape growing moreover results in additional environmental and health benefits. Nero, an interspecific cross between Eger 2 (Seyve-Villard 12375 selection) and Gárdonyi Géza (Medoc noir x Csaba gyöngye), is one of Hungary's most promising interspecific grape cultivars which gained an international interest recently. Our aim was to examine the flavonoid and anthocyanin composition for this interspecific variety during different harvest times in three consecutive vintages. The date of harvest and vintage played a significant effect on grape and wine quality. Further aim was to examine the Nero in the context of climate change on one given terroir. As summary we can conclude that Hungary's continental climate and the weather extremes and anomalies are the main factors affecting the quality of grape and wine. It also has to take into account the importance of the harvest date. The date of harvesting could affect the quality in both negative and positive way. Further research is needed in different vintages and terroirs and with more variables due to the climate change.

Variations of concentration of several phenolic components of Bianca experimental wines were followed in terms of vintage and harvest time during 2012, 2013 and 2014. There were remarkable differences in the main climatic characteristics among the vintages. Variations in five phenolic components GA (gallic acid), CA (kaftaric acid), CAT (catechin), eCAT (epicatechin), PrA (protocatechuic acid)) were followed in the experimental wines from three harvest times per vintages. The experimental vineyard is located at Eger, Kőlyuktető. The aim of the experiment was to assess the combined effect the vintage and the harvest time on some wine quality parameters. Based on the results, we can conclude that both factors had significant effects on wine analytical parameters. Interestingly, almost in the case of each parameter, the changes in concentration were clearly influenced by the vintage. Indeed, taking the changes in concentration in GA, it can be seen an increasing tendency during the ripening in 2012 and 2013. In contrast, in 2014 decreasing values were detected harvest by harvest. The effect of moderate and severe water deficit was examined on berry skin phenolic concentration and composition of the Kékfrankos variety (Vitis vinifera L.). Moderate water stress induced higher concentration of anthocyanin derivatives compared to the non-stressed plants with, the exception of Cya-3-g. Concentrations of some anthocyanin derivatives (Mal-3-g and Peo-3-g) were also higher in the severely stressed berry skins than in the control berries. No differences were found between the stressed and the non-stressed plants in the case of Cya-3-g. Similarly, concentration of some phenolic components (ie. protocatechuic acid, gallic acid, vanillic acid, trans-resveratrol etc.) increased as a result of water deficit. On the other hand, others such as quercetin-3-glucuronide decreased as the water deficit increased. In general, water deficit had a beneficial effect on grape phenolic concentration; however it can be modified by the changes in berry skin/flash ratio.

II. Effects of climate change and adaptation

We performed the survey with OAGCM results by the IPCC AR5 (2014) Report, considering not only the average maps of the projected changes, but also the bias-type errors in reconstruction of the recent climate, and also by standard deviation among the projected change patterns. Since these GCM results provide the boundary conditions to the embedded regional climate models (RCM), it is absolutely sad that the GCMs are not able to adequately represent the frequency of blocking anticyclones in the Atlantic-European region. Nevertheless, GCM mean fields are one of the approaches to regional climate scenarios. The potentially more promising approach is distributed by numerical results of the CORDEX Project coordinating RCM model-runs for various regions of the world, including Europe. The third sources of the scenarios, are the newest adjusted results by the four models run in Hungary. Having compared the GCM and RCM based patterns of changes, for seasonal temperature and precipitation, the differences are not big either for Europe or for North-East Hungary.

Having analysed the continuous observation series at Eger, Kőlyuktető, the following trends can be established: The annual mean temperature exhibits an increasing trend with a slope of 0.15 K/decade. The correlation coefficient of this linear relationship is 0.33 which is significant at 95% level. As concerns the annual mean precipitation, no significant correlation (r=0.04) could be found. Contrary to this finding, he annual sum of sunshine duration exhibits highly significant correlation (r=0.57) with time. The absolute increasing trend is 85 hours/decade which corresponds to 0.7%/decade. These results are considered as observed proof of model-based climate scenario.

Mainly expected projections of the climate models are expected projections for Europe, Hungary and Tokaj wine district were calculated and published. Recent climatic warming trends are evident from observational studies, and investigating the likely impact of climate change on biological systems is of substantial importance. In our study MaxEnt modelling approach was used to predict the possible effect of climate change on the distribution of winegrape (Vitis vinifera) across Europe using basic bioclimatic variables. Projections by the Hadley Centre Coupled Model 3 and Commonwealth Scientific and Industrial Research Organization MK3, were used to obtain potential changes in climatic suitability for growing winegrapes. The area loss is calculated for the main wine-producing countries in Europe, Portugal, Spain, France and Italy. Annual mean temperature was significant to model performance, and predicted suitable areas fitted well against the known winegrowing regions. Future predictions showed consistent changes based on a range of climate scenarios, with winegrowing regions predicted to shift northward. At the same time, additional problems may arise in the Mediterranean region as the most significant area loss is predicted for these regions. The predicted range stability until 2050 is dynamic, implying adaptations such as changing of grape cultivar and selection or modification of grapevine management could be necessary even in those regions which remain suitable in the future. Area loss was considered for only those locations where viticulture was covered by the CORINE database. This approach provides more realistic information, since the area suitable for winegrape cultivation is evidently much larger than the realised range.

Changing climatic conditions of Hungarian wine growing districts were studied previously on a regional scale. Our goal was to give a more accurate estimation of the growing season's temperature conditions in the vineyards of Eger region (North-eastern Hungary) for the middle and the end of the 21st century, focusing on two main parameters: the Heliothermic Index and the Cool Night Index.

Daily minimum, maximum and mean temperature data series of three different sources were used: 1) automatic meteorological stations located in the vineyards, 2) E-OBS gridded database, 3) PRECIS regional climate model outputs. The calculations were interpolated to one grid cell which represents the entire region. Daily mean temperature showed an increase of 0.5 °C in the past 50 years. Heliothermic and Cool Night Index values also increased. The vineyards' meteorological stations showed positive anomalies in Heliothermic Index and Cool Night Index values compared to the E-OBS dataset. The average daily mean temperature is projected to be 14.7 °C at the end of the 21st century, which means an increase by 5.1 °C compared to the 1961-1990 reference period. For the middle of the 21st century results predict an average value of 2485 °C for the Heliothermic Index, and 14.1 °C for the Cool Night Index in an "average" vineyard. For the end of the 21st century the projected average values of the Heliothermic Index and Cool Night Index are 2944 °C and 16.8 °C, respectively.

The temperature and precipitation conditions from 1900 onwards were reviewed, to establish possible trends. In the Tokaj region, temperature trend line drawn based on the measured temperature show more than 2^{o}C degreases increase over the last century, which fits well with the trend of global temperature change. Development of grape vines were very fast in the last years, so the harvest were earlier than in the last century. Data suggested that in the future the annual temperature will increase and the number of hot summer days also will increase. An increase in the summer drought, and the vegetative stages of vines are expected. Wood diseases are exacerbated by heat and drought stress. We have found that the topology of the soil and the terrain can exacerbate the occurrence of GTD diseases at local level.

Grapevine Trunk Diseases (GTD) are of great importance worldwide, including Hungary, a Central European country with long wine producing history. Several GTD pathogens have been described till now in Europe, but only a few from Hungary. The presence of a GTD pathogen in the vine does not necessarily result in the immediate appearance of disease symptoms, and information on the importance of environmental factors related to disease incidence are still limited. The aim of this research was to assess the occurrence of GTD in the Tokaj Wine Region, and to determine the biotic and abiotic factors influencing disease incidence. Five vineyards within 15 km radius – each with different topology, soil types, varieties and age – were studied for three consecutive years (2013 – 2015).

Fig. 5. Sampling sites in the TokajWine Region, Hungary in 2013–2015. 1. Szemere vineyard; 2. Dorgó vineyard; 3. Várhegy vineyard; 4.Bakonyi vineyard; 5. Szarvas vineyard)

The incidence of GTD-infection was determined every year for each vineyard. Diplodia seriata was isolated with incidence ranging from 50 to 100%, while Diaporthe spp. were the only other – minor – GTD pathogen found. Topology and soil type appeared to be major abiotic factors affecting incidence of GTD symptom. Disease incidence was also positively correlating with the age of the vineyards, and it was in fact found to be the definitive biotic factor regarding incidence. In contrast, D. seriata infection rate appeared unrelated to disease incidence or to any of the biotic or abiotic factors investigated.

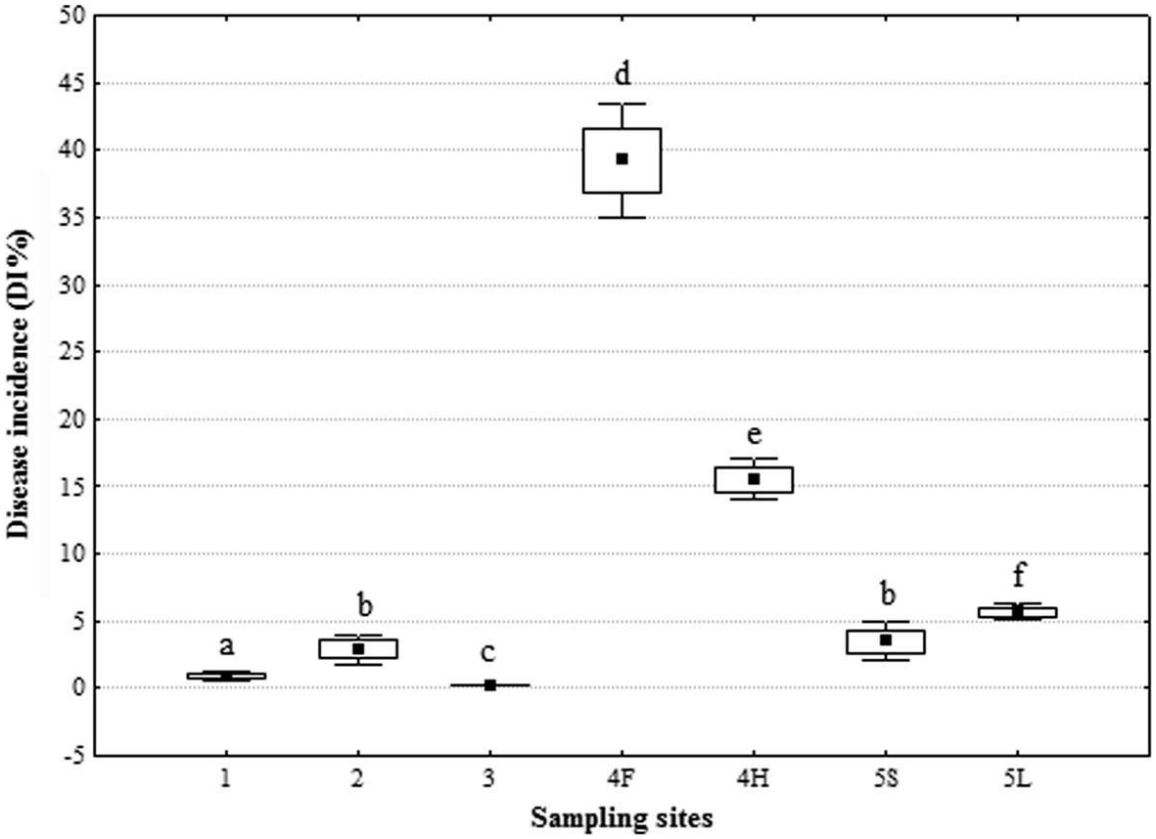

Fig. 6. Mean disease incidence (DI%± SE/SD) at the different vineyards in the Tokaj Wine Region, Hungary between 2013 and 2015. Letters indicate significant differences ($p < 0.05$) according to Mann–Whitney Utest. Number of sampling sites according to Fig 5.

Data of sugar concentration, titratable acidity and pH parameters of three grapevine varieties from Kőlyuktető. The investigated varieties processed form the last 28 years are Kékfrankos, Nero, Leányka. In this period the annual mean temperature and the annual sunny hours shows an increasing trend, however no significant trend were observed in annual precipitation The mean annul temperature increased approximately by 0.5 K by 2015. Similarly, the annual sunny hours increased from 1900 to 2100 hours. In parallel, the collected harvest data presents clearly decreasing or increasing values during this period showing a relationship between some climatic trend and must quality parameters.

Must sugar concentration definitely increased from 1987 to 2015. At the beginning of this period, the sugar concentration was around 200 g/L, by the last years this value was around 250 g/L in the case of each cultivar. However, a certain fluctuation was observed year by year in this parameter. Titratable acidity shows a significant decrease from 1987 to 2015. At the beginning of this period the acidity was 8-10 g/L, by the end of the period, it was 5-8 g/L in the case of all cultivars. Similarly to the must sugar concentration, fluctuation was also observed in this parameter during the experimental period, but no trend was observed in pH.

III. Terroir-scale analysis: effect of weather and climate on plant development

Terroir level temperature data were measured on the emblematic Nagy-Eged-hegy and Nagy-Eged-dűlő in Eger wine region (South, South-Western slopes of Bükk mountain) producing high wine quality each year. Due to the climate change, detected also in this wine region, very high alcohol content is emerging in the wines. Wine styles of the production are changing in these terroirs. Effect of summer heat stress has to be examined at the plant/fruit zone level.

Microclimatic sensors were mounted in the fruit zone of Vitis vinifera L. cv. 'Kékfrankos', the most abundant red grape cultivar of the region and of Hungary, planted at 3 different elevations along the hill slope. The sensors measured temperature data with 5 minutes' interval from July to mid-October. Our data suggest that there are at least 3 main temperature zones along the hillside. The daily changes of temperature are different in the 3 zones. The day/night temperature minimum and maximum values are highly affected by elevation, the bedrock and airflow of the slope.

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 grown in many vineyards along the wine region resulting in different wine quality and style depending on slope, elevation, aspect, soil and microclimatic conditions. In our 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). Measurements were taken in 2015 July-October.

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. 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.

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 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. 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.

Crop and plant growth on terroir level. Analytical parameters of experimental wines of Kékfrankos, Leányka, Olaszrizling, Nero, Bianca were collected, processed and analysed for 1995-2015 at Eger, Kőlyuktető. Based on the collected data, the titratable acidity of the wine showed a declining tendency during the experimental period, in the case of each cultivar. In most varieties alcohol concentration slightly increased between 1995 and 2015, however some extremities were observed in data during this period. In the case of the Kékfrankos variety the average alcohol concentration was 12,36 V/V% between 1995 and 2004 with an increasing values. Between 2005 and 2008 higher alcohol concentrations were measured (13,5 - 15 V/V%.) compared to the previous and the following (2009-2015) periods, whereas between 2008 and 2015 the concentration of the observed parameter was higher than between1995 and 2004. Very similar results were observed in the case of Olaszrizling, Nero and Bianca varieties, however no remarkable trends were observed in the case of the Leányka variety.

Effect of terroir, harvest time and climate on grape maturity and wine composition (Eger wine district), This experiment was carried out in two vineyards with different environmental conditions:
Kőlyuktető: This is a flat, commercial vineyard with brown soil formed on rhyolite tuff, with 39-42 % clay content, increasing towards to the deeper layers. Water-holding capacity of the soil is 36-38% and the wilting point is at 24-27%: Soil pH was slightly acid, especially in the upper parts. Sand fraction is 23-38 %, decreasing as we move downwards.
Eger-Nagyeged hill: This was a steep-sloped, commercial vineyard with a southern exposure resulting in rapid precipitation runoff and high radiation loads, and thus a general water deficit in the soil during the growing season. The brown soil was formed on marine limestone. Clay content is 21-24 %. The silt fraction (40-55 %) was dominant. Water-holding capacity is 25-27%, wilting point is at 12-14% and the pH was neutral. Based on GPS coordinates, the distance between the two vineyards is 6.97 kilometres. Nine blocks were selected randomly within each 0.5 hectare of the vineyard, including 40 plants by each block. The marginal rows were excluded. Climatic data were collected by automatic Boreas weather stations. In situ gas-exchange parameters were measured with a CIRAS-1 infrared gas-analyser (PP System, UK) in 6-8 replicates per sampling at 12.30 am (local time). Measurements were taken on different plants, on mature, undamaged leaves that had grown fully-exposed to the sun. During the gas-exchange measurements there were no significant differences between the samplings with regard to light intensity (PAR), relative humidity (RH) and air temperature (T).

Three harvest times were carried out in each year at both terroirs. Harvests were carried out at the same time in both vineyards in each year and their dates ranged between 15th September and 15th October. Each year, 30-40 kg of grapes were collected from the randomised blocks separately (three replicates from both vineyards per harvest time). Grapes were crushed, must sugar concentration was quantified and titratable acidity was determined from the juice samples. Wine phenolic concentration showed remarkable differences between the years and the harvest dates. The expression of some phenolic compounds showed a strong relationship with the vintage characteristics. In other cases, no remarkable vintage effects were found. The type of terroir has also a significant effect on the concentration of some phenolic components.

IV: Integration of the terroir-results into the recommendations on adaptation to climate

The vintage of 2018 was very warm and unusually dry. Therefore, vine growing stages started two three weeks earlier compared to the previous years. The vintage was suitable mainly for the red varieties. In the case of the whites high sugar content, decreased acidity and aromatic potential were observed. These characteristics were more emphasised if the harvest date delayed. Also, sugar concentrations of the red varieties increased fast, and kékfrankos variety reached the sugar ripeness in some terroirs, by the second part of September. However, climatic condition was favourable for the phenolic maturity of the grape berry. Red wines of this vintage are generally rich and full bodied, with high alcohol content.

Data of growing stages show, that bud break was very early in 2018. Comparing the data of the last 15 years, it seems that this is a trend, which shows that bud break generally started earlier and earlier from 2002. We can say that in 2018 it is true for other growing stages as well (i.e. flowering, berry set, veraison etc.), however no any trends were observed in these cases in the last 15 years.