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GEOMORPHOLOGY AND WINE: THE CASE OF MALVASIA IN THE VIPAVA VALLEY, (SLOVENIA)

GEOMORFOLOGIJA IN VINO: PRIMER SORTE MALVAZIJA V VIPAVSKI DOLINI

Petra Jamšek Rupnik, Franc Čuš, Andrej Šmuc

PRIMOŽ RUPNIK

Vineyards spreading across the slopes of the Vipava valley.
Vinogradi se razprostirajo prek pobočij Vipavske doline.

Geomorphology and wine: the case of Malvasia in the Vipava valley, Slovenia

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ABSTRACT: The concept of terroir incorporates interaction between geogenic and anthropogenic parameters and defines the typicity and quality of wine in a particular geographic area. Geomorphology represents one of the most important geogenic parameters of terroir. In 2008 we produced two wines from two different sites located within the same vineyard in the Vipava valley (Slovenia). Despite identical vine-growing and winemaking techniques, the two sites yielded grapes and wines of different quality. Both sites are identical in terms of macroclimate and bedrock, thus the differences are related to soil composition, drainage and microclimate, all directly linked to different geomorphic positions.

KEY WORDS: terroir, geomorphology, soil, drainage, microclimate, wine, Malvasia, Vipava valley, Slovenia

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1 Introduction

Geomorphological characteristics of wine-producing areas represent an important part of winemaking. They are included in the concept of **terroir**, which incorporates the interaction between geogenic and anthropogenic parameters and defines the typicity and quality of wine (e.g. Wilson 1998; Meinert 2004; Hugget 2006). Beside geomorphology, geogenic parameters of terroir include bedrock, hydrogeological and pedogenic characteristics, and climate. Anthropogenic parameters of terroir include specific vine-growing and winemaking techniques. Despite the fact that geogenic factors of terroir affect grape yield, vine vigour, and fruit quality (e.g. Trought et al. 2008), the relative importance of individual factors remains controversial due to their interaction and variability in time (e.g. Wilson 1998; Meinert 2004).

Vineyards in Slovenia extend over approximately 16,000 ha with an average annual production of ~70 million litres of wine, ~8 million litres being exported and ~9 million imported (Zagorc et al. 2014). Wine consumption amounts to 39 L per capita, placing Slovenia among the top five European wine consumers (Čuš et al. 2007). Therefore, winemaking is an important part of the Slovenian economy, the focus of research, however, has been mainly on grapevine varieties, training systems, cultivation techniques, etc., while physical elements of terroir have been neglected.

The present study examines the importance of geomorphic factors and attempts to define the spatial scale on which they influence the wine. We performed interdisciplinary research on the Malvasia (*Vitis vinifera* L.) terroir in the Vipava valley (Figure 1) that included all fundamental geogenic and anthropogenic

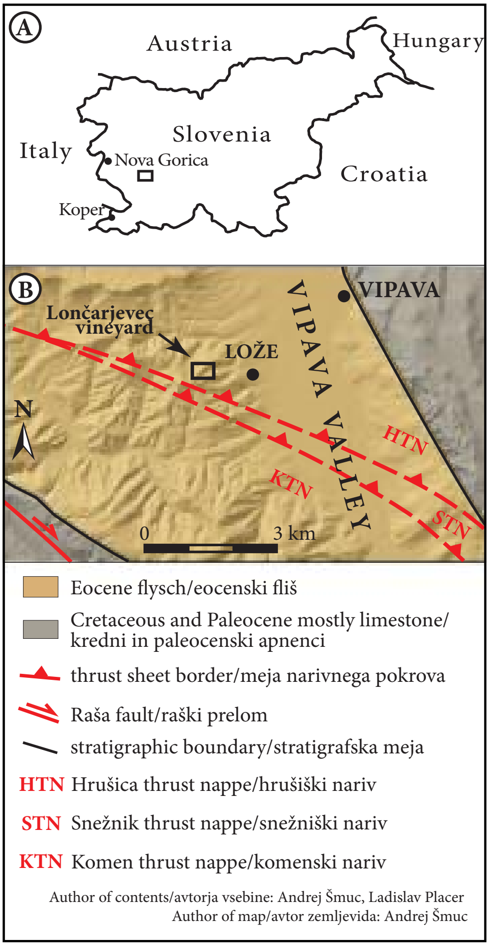

Figure 1: (A) Location of the studied area. (B) Generalized tectonic map of the Vipava valley (modified after Placer 1981) with location of the studied vineyard.

aspects of terroir. To separate the role of geomorphology, other geogenic and anthropogenic factors had to be the same. The selected Lončarjevec vineyard (Figures 2 and 3) was the perfect candidate: a) the vineyard bedrock is uniform; b) the vineyard is small enough to ensure the same macroclimate; and c) the investigated Malvasia was planted in the same year in two distinct topographic localities within the same vineyard, hereafter reffered as the Upper Malvasia (UM) planted on a terraced slope and the Lower Malvasia (LM) planted in the valley bottom, though both are of the same variety. With identical vine-growing and winemaking techniques two wines were produced from the two vineyard sites in 2008, allowing a direct comparison with differences in terroir.

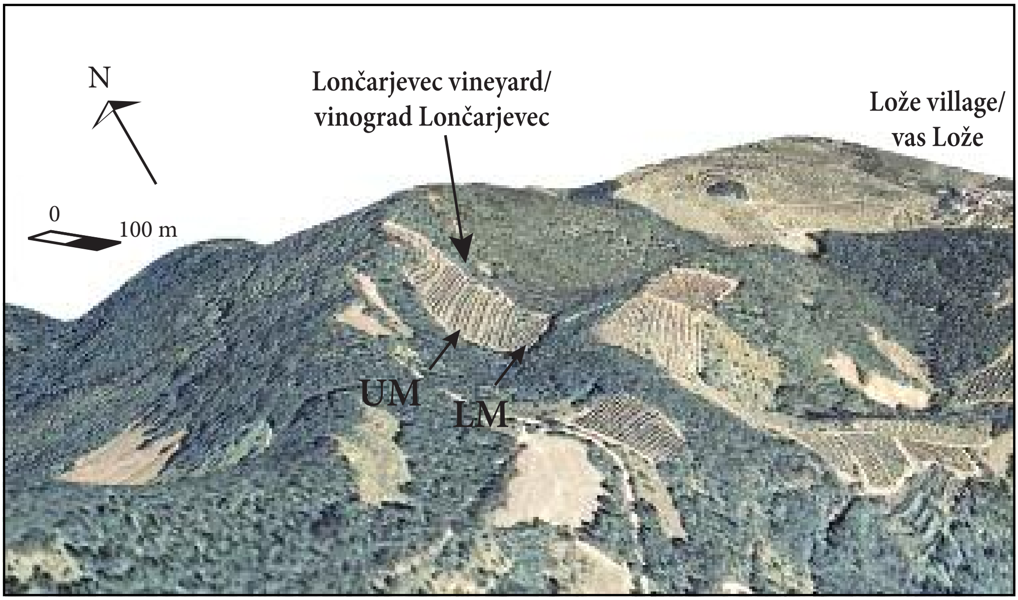

Figure 2: Orthophoto image of the study area (recorded in 2006) over the DEM 5 m resolution (The Surveying and mapping authority of the Republic of Slovenia 2014).

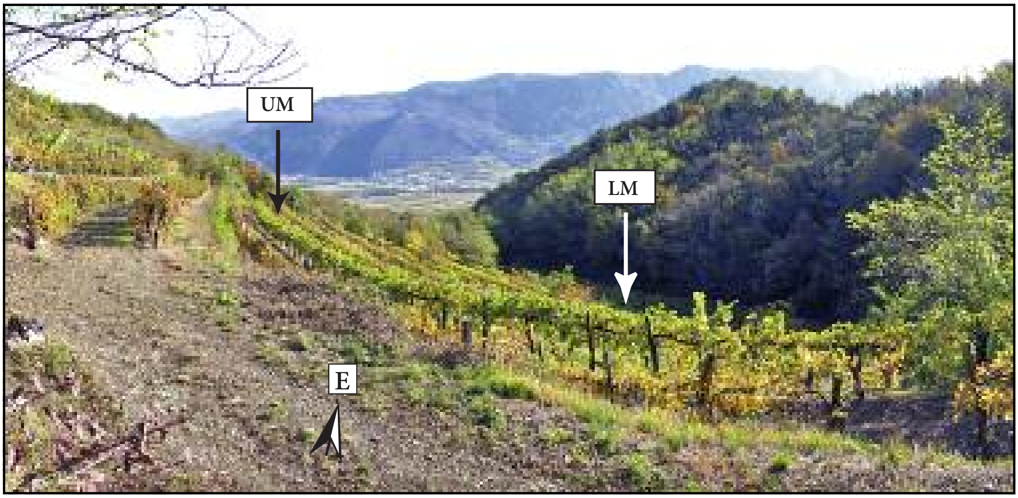

Figure 3: Lončarjevec vineyard with marked UM and LM sites.

2 Materials and methods

2.1 Bedrock

Detailed geological mapping of the vineyard at 1 : 5,000 scale was done in order to define the bedrock conditions.

2.2 Soil

Soil samples were collected according to the methodology described in ISO 10381-1,2,4 (2002/2003) in April 2009, eight months after the last tilling, from two studied rows in the vineyard and from two depths: 0–20 cm, and 20–40 cm. Two representative soil samples for each site (0–20 cm and 20–40 cm sample) were made up of a composite of five subsamples taken at even distances across the row, ~20 cm away from the vines. After a week of air-drying at 25 °C, the samples were disaggregated, sieved to 2 mm to remove parts of the substratum (skeleton), and then ground in a mechanical agate grinder to a fine powder < 63 µm. The mineralogical composition was identified via X-ray diffractometry (XRD, Philips, PW 1820) on unoriented powder mounts (Cu Kα / Ni 40 kV, 30 mA) with the X'Pert HighScore software program. Elemental composition of soil samples was analysed in a certified commercial Canadian laboratory (Acme Analytical Laboratories, Ltd.) after extraction for 1 h with 2-2-2- $HCl–HNO_3–H_2O$ at 95 °C by inductively coupled plasma mass spectrometry (ICP-MS). The accuracy and precision of the soil analyses were assessed by using international reference material such as the Canadian Certified Reference Material Project (CCRMP) SO-1 (soil) and United States Geological Survey (USGS) G-1 (granite).

2.3 Climate

Climatic data were obtained from the nearest automatic meteorological station, located in the Bilje village, 25 km westward from the studied area. Monthly and daily temperature and precipitation data are available from ARSO (2015).

2.4 Grapes and wine

Five healthy and normally grown vines were randomly selected in each of the vineyard sites to examine the grape yield and grape quality. The grape yield was estimated by weighing grape clusters of each vine. Samples of 100 randomly selected grapes were collected from 10 grape clusters per vine taken from all sides of each grape cluster. All grapes were weighed and pressed manually. Pressed juice was left to settle and then the sugar content was measured by digital refractometer as well as the total acidity (g/L of tartaric acid) and pH value (OIV 2012).

60 vines from each vineyard site were harvested on 19 September 2008 to produce two wines. Grape processing and vinification were the same for both wines. Grapes (~200 kg/site) were destemmed, crushed, and pressed. Must (~140 L/site) was poured into stainless steel tanks and potassium metabisulphite was added (0.1 g/L). The must (~120 L/site) was decanted after 36 h, and then rehydrated dry yeasts (*Saccharomyces bayanus*) were added (0.2 g/L; Enologica Vason). Yeast nutriment (0.2 g/L) was added the next day (V ACTIV, Enologica Vason). Alcoholic fermentation lasted for four days at a temperature of 15–18 °C. Seven days after the fermentation was completed, the wine was decanted (~110 L/site) and 0.1 g of potassium metabisulphite per litre was added. Alcohol level, total acidity, residual sugar, and pH value of the wines were measured one month after the completed fermentation using the reference methods by the OIV (2012).

3 Results

3.1 Geological setting

The bedrock of the vineyard and its surroundings consists of Eocene flysch with intercalated calciturbidite beds (Figure 4). The vineyard itself is underlain only by siliciclastic flysch represented by an alternation of sandstones, siltstones and marls. Intercalated 1–20 m thick carbonate beds (carbonate breccias and calcarenites) form the edges of the vineyard.

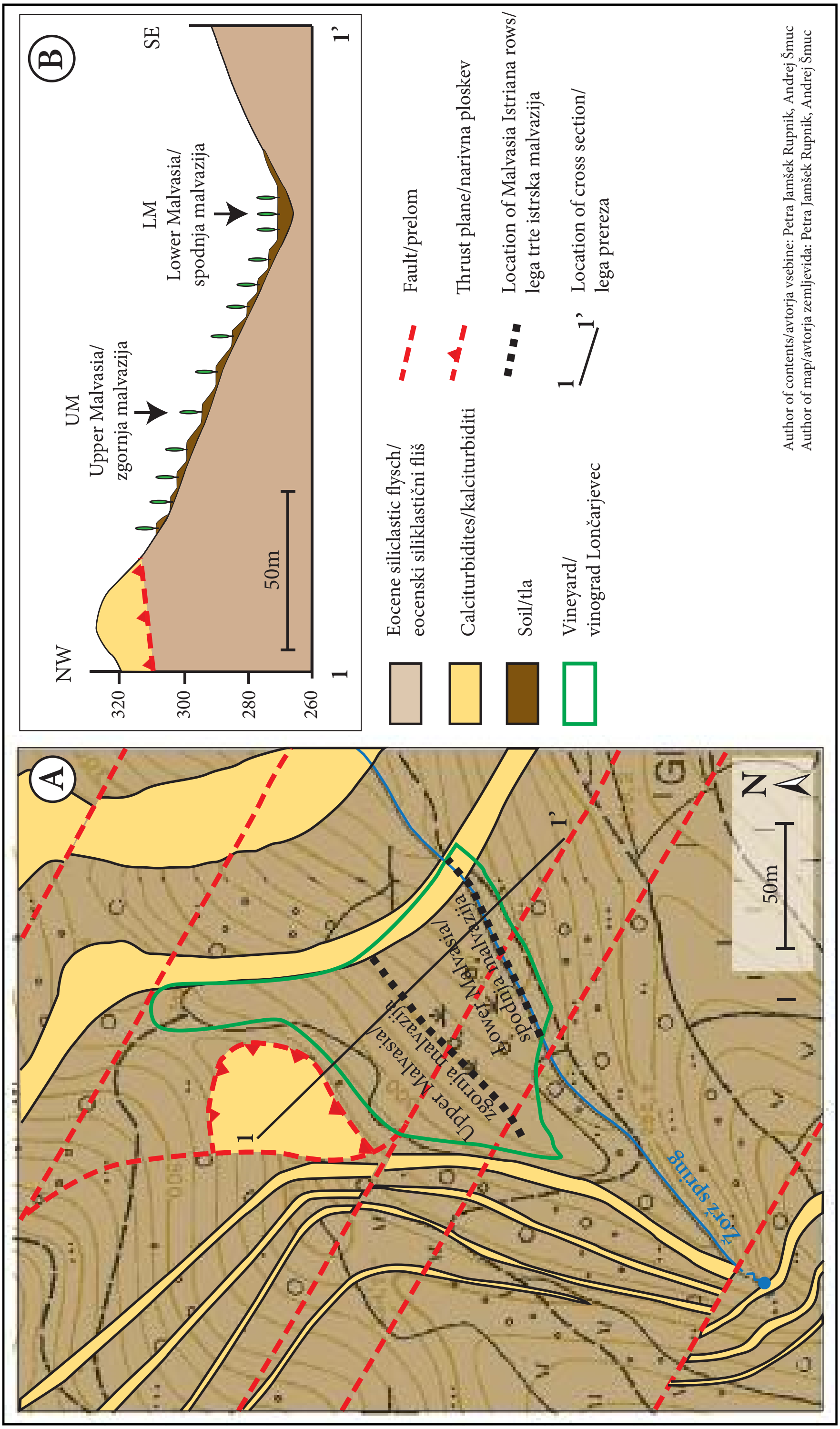

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Figure 4: Geological map (A) and profile (B) of the Lončarjevec vineyard.

3.2 Geomorphology

The development of the present landforms of and around the vineyard resulted mainly from Neogene-to-recent thrust and strike-slip tectonics, evolution of the fluvial-drainage network, differential erosional processes due to lithological differences in Eocene flysch succession (carbonate rocks being more resistant to weathering, cf. Komac and Zorn 2008) and subsequent slope processes (cf. Zorn 2009; Popit et al. 2014). The vineyard lays on a southeastern slope (Figures 4, and 5); the upper part is on a steep slope (~ 50% inclination) stretching between altitude of 270–310 m, while the lower part is on a flat valley bottom at 270 m altitude. The slope is terraced to individual terraces 3.5–4.0 m wide and UM is located on the 6th terrace from the bottom. UM has south-east exposure, LM on the other hand is located on a relatively flat surface.

3.3 Hydrogeological properties

The siliciclastic flysch has low permeability with hydraulic conductivity in the range of 1.10^{-6} to 1.10^{-7} m/s (e.g. Janža and Prestor 2002), while intercalated thick carbonate beds have fracture water conductivity with hydraulic permeability several orders of magnitude higher than flysch (e.g. Verbovšek 2008). Areas with flysch bedrock are characterized by a dense network of small and usually non-perennial watercourses draining water from the surface and subsurface. The intercalated carbonate beds in these areas can form smaller aquifers. Within the vineyard the water is drained on the surface or subsurface from the slopes towards the valley bottom where also a few weak springs occur on the carbonate/flysch contact. At the valley bottom waters merge into the Žorž spring (Figure 4) with a torrent character.

Hydrological properties differ within the vineyard. Slope of the vineyard has a relatively fast surface and subsurface drainage and is therefore drier, while the valley bottom is usually wetter due to slower drainage and larger quantities of received waters.

3.4 Pedological properties

The soil of the vineyard was derived from Eocene flysch mainly by direct organic and weathering breakdown and slope redeposition. Fine grained loamy clay vitisol is regularly tilled and homogenized, with a neutral pH (7.0) and cation-exchange capacity at 20–35 milliequivalent of hydrogen per 100 g of dry soil.

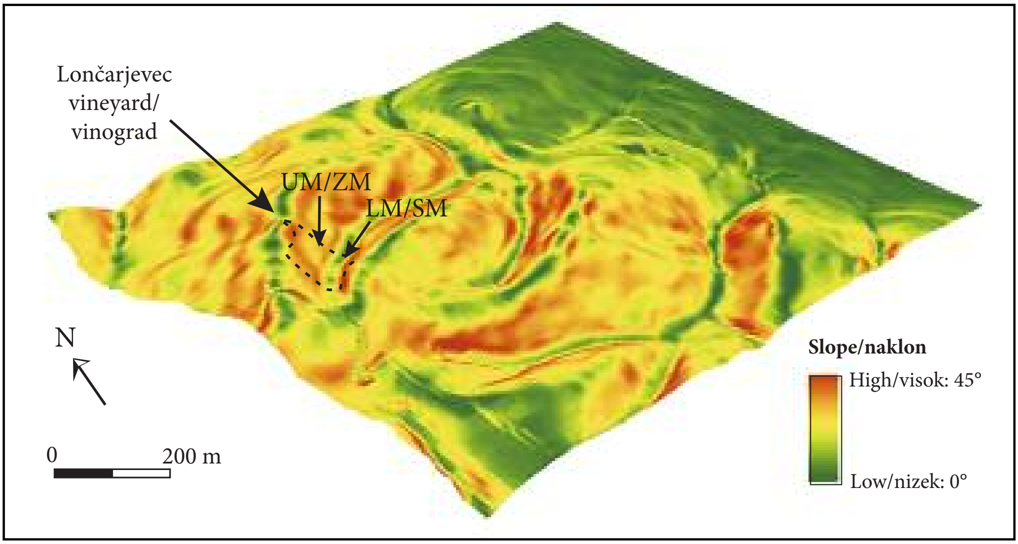

Figure 5: Slope map derived from 5 m resolution DEM (The Surveying and mapping authority of the Republic of Slovenia).

The soil thickness in the vineyard varies; on a slope it is from 20 cm on the inner side to up to 2 m on the outer side of the terrace, while at the valley bottom it is 2–5 m thick.

X-ray diffraction of soils show the overall mineralogy is comparable within the vineyard; however some differences occur (Table 1). The LM soils contain more abundant clay minerals of montmorillonite and clinoclore, whereas the UM subsurface soils contain calcite.

Table 1: Identified minerals in UM and LM soils.

Site	Soil depth [cm]	Quartz	Muscovite Illite	Albite	Clay minerals		Calcite
					Montmorillonite	Clinochlore	
LM	0–20	✓	✓	✓	✓	✓	×
	20–40	✓	✓	✓	✓	✓	×
UM	0–20	✓	✓	✓	×	×	×
	20–40	✓	✓	✓	×	✓	✓

Soil geochemistry show the content of major elements is again quite similar for both sites, with some differences (Table 2); the UM soil is enriched in MgO and CaO and has lower P_2O_5 content than LM. These results show good concordance with mineralogical study that identified carbonate in the UM soil.

Table 2: Major element concentrations in UM and LM soils (values are in %).

Site	Soil depth [cm]	SiO_2	Al_2O_3	Fe_2O_3	MgO	CaO	Na_2O	K_2O	TiO_2	P_2O_5	MnO	LOI
LM	0–40	58.5	14.8	6.2	1.4	1.2	0.9	2.8	0.7	0.19	0.18	13.0
UM	0–40	60.3	15.8	6.7	1.7	1.7	0.9	2.8	0.8	0.13	0.21	8.9

3.5 Climatic characteristics

The Vipava valley has a specific transitional climate that represents a mixture of Mediterranean and continental climate influence. The mild climate of the valley is often interrupted by a strong northeasterly wind

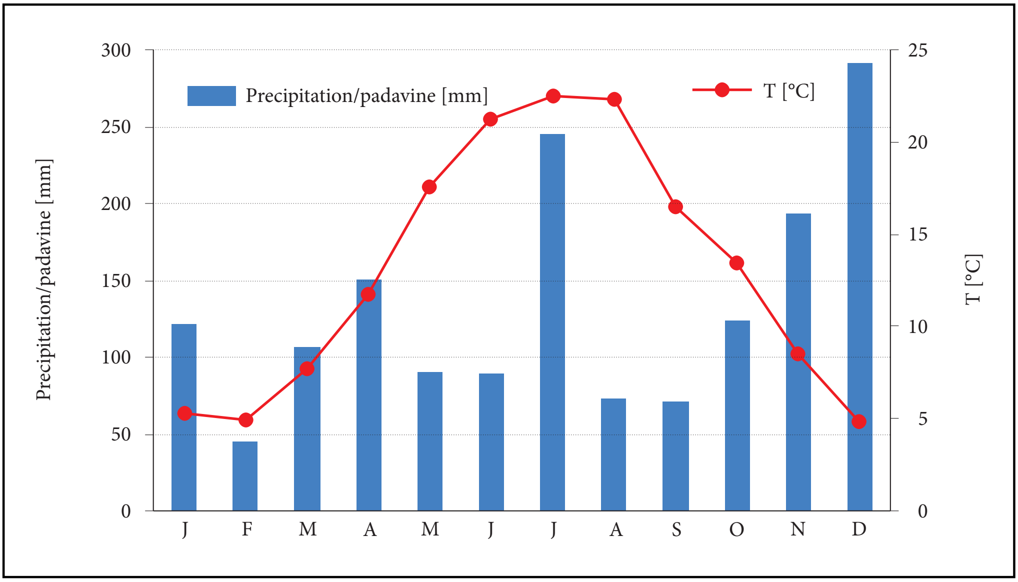

Figure 6: Average air temperature (lines) and monthly sum of precipitation in 2008 (ARSO data source 2015).

Bora that can reach a speed of 200 km/h (e.g. Mihevc 1997). The annual rainfall in the area is between 1,400 and 1,700 mm (ARSO 2015). The majority of rainfall is in spring and autumn, while winter snow is rare. The second part of July and August is usually the drier season, with uneven distribution of short-lasting and torrential rain followed by longer periods with minimal rainfall, higher temperatures, and wind. During 2008 the annual precipitation was 1,601 mm, 110 % of the 1961–1990 average, and the average annual air temperature was 13 °C (Figure 6, ARSO 2015). During the winter the daily average temperatures dropped below 0 °C for six days, while daily average temperatures in summer reached up to 27 °C (ARSO 2015). The area received 2,136 h/yr of solar radiance, 101% of the 1961–1990 average (ARSO 2015).

Microclimates of the vineyard differ. The UM site enjoys strong solar radiance but is more exposed to the Bora wind. The LM site receives less solar radiance and is more prone to frost but less exposed to the Bora wind.

3.6 Anthropogenic parameters

The Lončarjevec vineyard is planted with 3,500 vines, of which 800 belong to the Malvasia variety, planted in April 1993, with a cordon training system *Casarsa*. Vine spacing is 2.2 m and row spacing is 3.0 m. Rows trend in NE–SW direction. The plant material and rootstock (Selection Oppenheim 4) for both localities is the same and originates from the Vrhpolje nursery at Vipava.

3.7 Grapes and wine

Results of analyses of yield and quality parameters of grapes and wines are shown in Table 3.

Table 3: Yield and quality parameters of grapes and wines.

	Parameters	UM	LM	Statistical significance (%)
Yield	No. of grape clusters per vine	19.4 ± 3.1	18.4 ± 4.8	70.8
	Weight of 10 random grape clusters per vine [g]	1,886 ± 241	1,970 ± 258	61.2
	Total weight of grapes per vine [g]	3,600 ± 400	3,700 ± 1,400	88.6
	Weight of 100 random grape berries per vine [g]	256.9 ± 10	262.5 ± 10.1	40.4
Grape quality	Sugar content [Öe]	83 ± 8	77 ± 3	18.2
	Total acidity [g/L]	10.3 ± 1.4	12.0 ± 1.5	10.4
	pH	3.20 ± 0.10	3.09 ± 0.03	9.3
Wine quality	Alcohol [vol. %]	10.9	10.4	
	Residual sugar [g/L]	0.9	1.2	
	Total acidity [g/L]	10.3	11.3	
	pH	3.22	3.10	

LM, and UM vines yielded similar number, and total weight of grape clusters per vine, but the average weight of 100 grape berries was higher on the LM site (Figure 7). Differences however were not statistically significant.

The average sugar content and pH was higher and the total acidity lower in the UM grapes (Figure 8). Only differences in total acidity and pH value are statistically significant with 10.4% and 9.3%, respectively.

The UM wine had higher alcohol content and pH and lower common acidity. The significance of the differences cannot be assesed however, since one wine was produced from each site.

4 Discussion

Despite very similar geologic, pedogenic, and macroclimate conditions, the quality of the UM and LM grapes differed, particularly in terms of total acidity and pH. The total acidity in wine influence the sensorial perception of acidity. Although the winemaking was done in only one sample per each site, the differences in total acidity and pH value in the wines confirmed the differences detected in the grape juice.

In a particular year, a must's total acidity depend mainly on geology, soil and climate, including soil humidity and permeability, rainfall patterns and temperature. The UM and LM sites have identical macroclimate and bedrock, significant differences in the wines are therefore related to different soil composition (1), drainage (2), and microclimate (3), which are directly linked to geomorphic positions of the sites.

1. The UM soil depth (20 cm to 2 m) allowed thorough tilling and better soil nutrients homogenization which could explain a slightly higher CaO and MgO content compared to the LM soil. In up to 5 m deep LM soil, tilling did not reach deeper horizons and did not recycle the CaO and MgO from deeper parts.

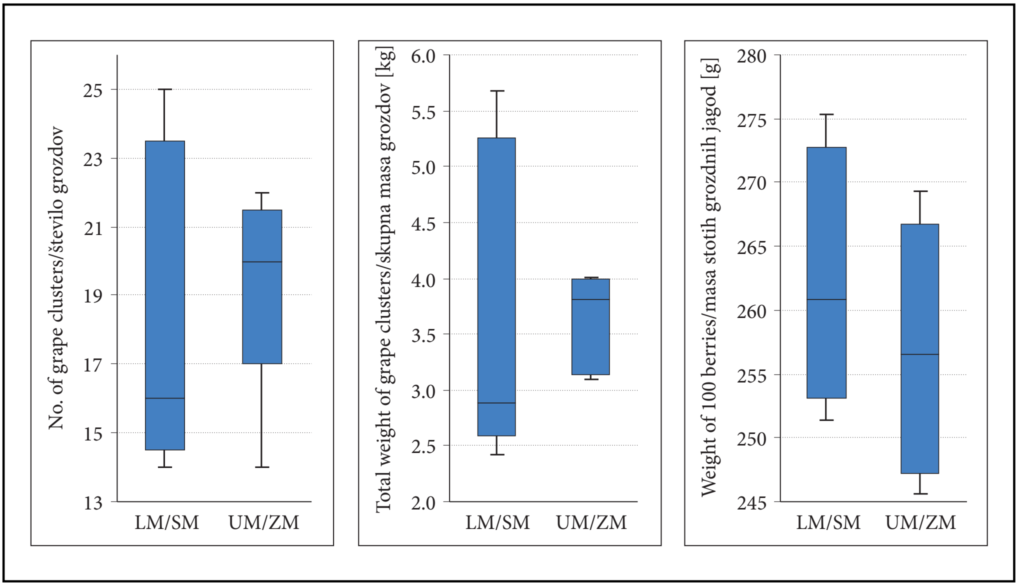

Figure 7: Whisker plots of grape yield parameters.

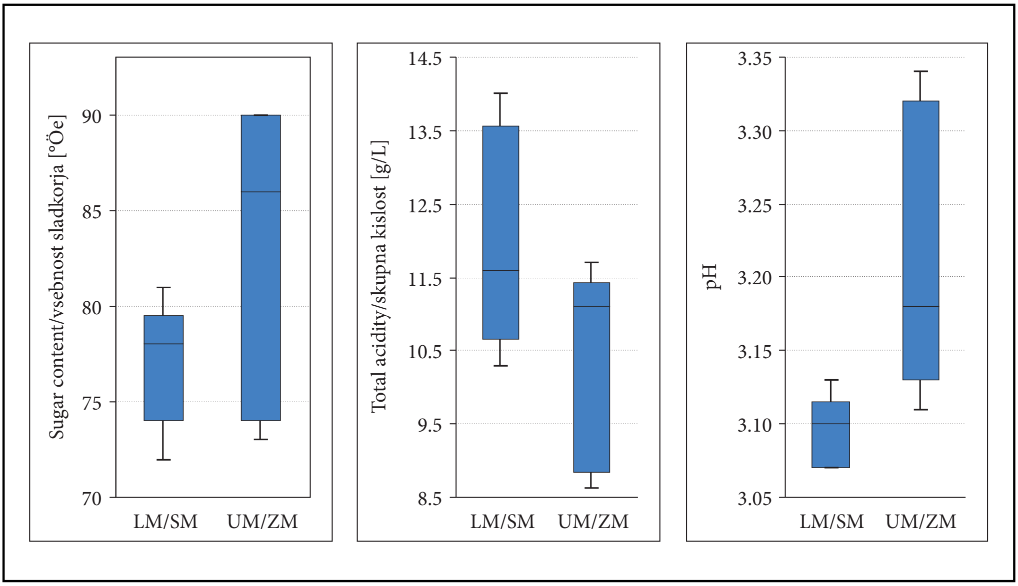

Figure 8: Whisker plots of grape quality parameters.

2. The steeper UM site allows far better drainage. This is partly a result of the mineralogical differences; the UM soils have lower clay minerals content because they are washed into lower soil parts and transported downslope, accumulating in the LM soils. Clays have higher water retention capacity and retard water drainage. Since a mild to moderate water deficit has a positive effect on the fruit and wine phenolic composition and the wine sensory characteristics (e.g. Zsofi et al. 2011) good drainage is essential.
3. Slope and its aspect influence the solar radiation load (Huggett 2006). The UM site enjoys stronger solar radiance, has stronger evapotranspiration rate and is less prone to frost. Higher clay minerals content in the LM soils also contributed to the faster heat loss affecting the acidity of the grapes and wines (cf. Huggett 2006).

5 Conclusion

In 2008 we produced two wines of Malvasia from two different sites within the same vineyard in the Vipava valley, one on the terraced slope and another in the valley bottom. With identical vine growing, and winemaking techniques the two sites yielded grapes and wines of different quality. Since the studied vineyard has uniform bedrock and the same macroclimate, significant differences in the grapes and wines are due to different soil composition, drainage and microclimate, which are directly linked to different geomorphic positions. Geomorphic position of not only the vineyard but also the vines within it influences wine quality.

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Geomorfologija in vino: primer sorte Malvazija v Vipavski dolini

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IZVLEČEK: Koncept terroirja združuje interakcijo geogenih in antropogenih parametrov, ki vplivajo na tipičnost in kakovost vina na določenem geografskem območju. Eden najpomembnejših geogenih parametrov terroirja so geomorfološke značilnosti vinograda. Iz dveh različnih leg v istem vinogradu v Vipavski dolini smo leta 2008 pridelali dve vini. Kljub enakim vinogradniškim in vinarskim tehnikam pridelave sta bili kakovost grozdja in vina iz obeh leg različni. Legi zaznamujeta enaka makroklima in geološka podlaga, torej so razlike, ki smo jih zaznali v grozdju in vinu, odvisne predvsem od sestave tal, drenaže in mikroklime. Ti parametri so neposredno povezani z različno geomorfno pozicijo raziskovanih leg.

KLJUČNE BESEDE: terroir, geomorfologija, tla, drenaža, mikroklima, vino, malvazija, Vipavska dolina, Slovenija

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1 Uvod

Geomorfološke značilnosti vinorodnih območij imajo pomemben vpliv na kakovost grozdja in vina. Vključene so v koncept terroirja, ki združuje interakcijo geogenih in antropogenih parametrov, ki vplivajo na tipičnost in kakovost vina (npr. Wilson 1998; Meinert 2004; Hugget 2006). Poleg geomorfologije geogeni parametri terroirja obsegajo še geološko podlago, hidrogeološke, pedološke ter podnebne značilnosti območja. Antropogeni parametri terroirja vključujejo način obdelave vinograda in proces pridelave vina. Geogeni faktorji terroirja pomembno vplivajo na uspevanje, rodnost trsov in kakovost grozdja (npr. Trought s sodelavci 2008), vendar njihov relativni pomen ostaja sporen zaradi interakcij in časovne variabilnosti (npr. Wilson 1998; Meinert 2004).

Vinogradi se v Sloveniji razprostirajo na približno 16.000 ha, povprečna letna pridelava vina znaša ~70 milijonov litrov, ~8 milijonov litrov je izvoženih in ~9 milijonov uvoženih (Zagorc s sodelavci 2014). Letna poraba vina znaša 39 litrov na prebivalca, kar Slovenijo postavlja med pet največjih potrošnikov vina v Evropi (Čuš s sodelavci 2007). Pridelava vina je zato pomemben del slovenske ekonomske dejavnosti. Raziskave so bile doslej bile usmerjene predvsem na sorte trsov, gojitvene oblike, načine obdelave, medtem ko so bili zapostavljeni fizični elementi terroirja.

Naše delo raziskuje pomembnost geomorfnih dejavnikov in skuša ugotoviti, na kakšnem prostorskem merilu le-ti vplivajo na kakovost vina. Interdisciplinarne raziskave smo usmerili na primer terroirja malvazije (*Vitis vinifera* L.) v Vipavski dolini (slika 1), vključujoč vse temeljne geogene in antropogene vidike terroirja. Da bi vlogo geomorfologije lahko ločili od ostalih dejavnikov, smo morali zagotoviti enake ostale geogene in antropogene razmere. Izbrani vinograd Lončarjevec (sliki 2 in 3) je bil v tem oziru idealen: a) geološka podlaga vinograda je enotna; b) vinograd je dovolj majhen za zagotavljanje enake makroklime in c) preiskovana sorta malvazija je bila v istem letu posajena na dveh različnih topografskih legah znotraj istega vinograda: na terasiranem pobočju (v nadaljevanju imenovano Zgornja malvazija – UM/ZM) ter na dnu doline (Spodnja malvazija – LM/SM); v obeh primerih gre za isto sorto. Z enakimi vinogradniškimi in vinarskimi tehnikami je bilo v letu 2008 iz vsake lege pridelano vino, kar je omogočilo neposredno primerjavo z razlikami v terroirju.

Slika 1: (A) Lokacija obravnavanega območja. (B) Generalizirana tektonska karta Vipavske doline (po Placer 1981) z lokacijo obravnavanega vinograda.
Glej angleški del prispevka.

Slika 2: Ortofoto obravnavanega območja (posnet v letu 2006) prek DMR z ločljivostjo 5 m (Geodetska uprava Republika Slovenije).
Glej angleški del prispevka.

Slika 3: Vinograd Lončarjevec z označenima legama ZM in SM.
Glej angleški del prispevka.

2 Materiali in metode dela

2.1 Geološka podlaga

Geološke razmere smo raziskali z detajlnim geološkim kartiranjem vinograda in njegove okolice v merilu 1 : 5.000.

2.2 Tla

Prst oziroma tla smo vzorčili aprila 2009, osem mesecev po zadnjem rigolanju, po metodologiji opisani v ISO 10381-1,2,4 (2002/2003). Vzorce smo pobrali iz dveh obravnavanih leg oziroma vrst trsov in iz dveh globin: 0–20 cm in 20–40 cm. Iz vsake lege smo izdelali po dva reprezentativna vzorca (0–20 cm in 20–40 cm), sestavljena iz petih pod-vzorcev, ki smo jih odvzeli enakomerno po vrsti trsov in v oddaljenosti ~20 cm od trsov. Po enotedenskem sušenju na 25 °C smo vzorce presejali skozi sito z 2 mm odprtinami, s čemer so bili odstranjeni večji delci matične podlage (skelet), in nato drobili v ahatski terilnici na zrnavost finega prahu < 63 μm. Mineraloško sestavo smo določili z rentgensko difrakcijo (XRD, Philips, PW 1820) na neorientiranih vzorcih (Cu Kα / Ni 40 kV, 30 mA) in z uporabo programa X’Pert HighScore. Elementna sestava vzorcev je bila izmerjena v akreditiranem kanadskem laboratoriju Acme (Acme Analytical Laboratories, Ltd.) in sicer s postopkom enournega izluževanja z 2-2-2- $HCl–HNO_3–H_2O$ pri temperaturi 95 °C ter visokoločljivostnim ICP-MS (masni spektrometer z induktivno sklopljeno plazmo). Natančnost in točnost analiz je bila ocenjena z uporabo mednarodnih referenčnih materialov, kot sta CCRMP SO-1 (zemlja) in USGS G-1 (granit).

2.3 Podnebje

Klimatske podatke smo pridobili iz najbližje avtomatske vremenske postaje v vasi Bilje, 25 km zahodno od obravnavanega območja. Podatki o mesečnih in dnevnih temperaturah in padavinah so dostopni prek ARSO (2015).

2.4 Grozdje in vino

Količino (rodnost) in kakovost pridelka smo izmerili na petih naključno izbranih zdravih in normalno razvitih trsih na vsaki od leg v vinogradu. Rodnost trsov smo ocenili s tehtanjem grozdja na vsakem trsu. Vzorec stotih naključno izbranih grozdnih jagod smo odvzeli iz desetih grozdov in iz vseh delov grozda. Jagode smo stehtali in ročno stisnili. Po bistrenju grozdnega soka s samousedanjem smo izmerili koncentracijo sladkorja, skupnih kislin (g/l vinske kisline) in pH (OIV 2012).

Na vsaki od obravnavanih leg smo 19. septembra 2008 potrgali grozdje iz 60 trsov in ga predelali v vino. Predelava grozdja in proces pridelave vina sta bila za obe vini enaka. Grozdje (~200 kg/lego) smo pecljali, drozgali in stisnili. Mošt (~140 l/lego) smo shranili v nerjavečo posodo in mu dodali kalijev metabisultif (0,1 g/l). Po 36 urah smo mošt pretočili (~120 l/lego) in mu dodali rehidrirane suhe kvasovke *Saccharomyces bayanus* (0,2 g/l; Enologica Vason). Naslednji dan smo dodali hrano za kvasovke (0,2 g/l; V ACTIV, Enologica Vason). Alkoholna fermentacija je trajala štiri dni pri temperaturi 15–18 °C. Sedem dni po zaključeni alkoholni fermentaciji smo vino pretočili (~110 l/lego) in mu dodali 0,1 g kalijevega metabisulfita na liter vina. Alkoholno stopnjo, koncentracijo skupnih kislin, reducirajočih sladkorjev in pH v obeh vinih smo izmerili mesec dni po zaključeni alkoholni fermentaciji po referenčnih metodah OIV (2012).

3 Rezultati

3.1 Geološka podlaga

Podlago vinograda in okolice gradi eocenski fliš z vmesnimi plastmi karbonatnih turbiditov (slika 4). Vinograd leži samo na siliciklastičnem flišu, ki ga sestavlja menjavanje peščenjakov, meljevcev in laporovcev. Od 1 do 20 m debele karbonatne plasti (karbonatne breče in kalkareniti) pa tvorijo robove vinograda.

Slika 4: Geološka karta (A) in profil (B) vinograda Lončarjevec.
Glej angleški del prispevka.

3.2 Geomorfologija

Današnje površje vinograda in njegove okolice je posledica neogenske–recentne narivne in zmične tektonike, razvoja rečne drenažne mreže, različnih erozijskih procesov zaradi litoloških razlik v eocenskem flišnem zaporedju (karbonatne kamnine so odpornejše proti preperevanju, cf. Komac in Zorn 2008) in sledečih pobočnih procesov (cf. Zorn 2009; Popit s sod. 2014). Vinograd leži na jugovzhodnem pobočju (sliki 4 in 5); zgornji del je na strmem pobočju z naklonom ~50 % na nadmorski višini 270–310 m, medtem ko je spodnji del v ravnem dolinskem dnu na nadmorski višini 270 m. Pobočje je terasirano na posamezne terase s širino 3,5–4,0 m in ZM leži na šesti terasi od spodaj navzgor. ZM ima jugovzhodno ekspozicijo, SM pa je na razmeroma ravnem površju.

Slika 5: Zemljevid naklonov površja izdelan iz DMR z ločljivostjo 5 m (Geodetska uprava Republika Slovenije).
Glej angleški del prispevka.

3.3 Hidrogeološke lastnosti

Siliciklastičen fliš je slabo vodoprepusten, njegov koeficient vodoprepustnosti je reda velikosti $1 \cdot 10^{-6}$ do $1 \cdot 10^{-7}$ m/s (npr. Janža in Prestor 2002), medtem ko imajo vmesne karbonatne plasti razvito razpoklinsko poroznost z nekaj razredov višjim koeficientom vodoprepustnosti kot fliš (npr. Verbovšek 2008). Za flišno pokrajino je značilna gosta hidrografska mreža majhnih in običajno nestalnih vodotokov, ki drenirajo vodo s površja in preperinskega sloja. Vmesne karbonatne plasti v teh območjih lahko tvorijo manjše vodonosnike. Znotraj vinograda se voda drenira po površju in pod preperinskim slojem s pobočja proti dnu doline, kjer se pojavlja nekaj šibkih izvirov na stiku karbonatnih in flišnih kamnin. Na dnu doline se voda združi v Žoržev potok (slika 4), ki ima hudourniški značaj.

Hidrološke značilnosti znotraj vinograda so raznolike. Pobočje vinograda ima relativno hitro drenažo površja in preperinskega sloja ter je zato bolj suho, medtem ko je dno doline običajno bolj vlažno zaradi počasnejše drenaže in večje količine prejete vode.

3.4 Pedološke lastnosti

Tla v vinogradu so nastala iz eocenskih flišev predvsem z organskim in mehanskim preperevanjem ter pobočnimi premiki preperine. Drobnozrnati ilovnato-glinasti vitisol je redno rigolan in homogeniziran, ima nevtralen pH (7.0) in izmenjalno kapaciteto 20–35 miliekvivalentov hidrogena na 100 g suhih tal. Debelina tal je znotraj vinograda različna; na pobočju so debela od 20 cm na notranji strani do 2 m na zunanji strani teras, na dnu doline pa 2–5 m.

Rentgenska difrakcija vzorcev tal kaže, da je mineraloška sestava tal znotraj vinograda podobna, vendar se pojavlja nekaj razlik (preglednica 1). Tla SM vsebujejo več glinenih mineralov montmorillonita in klinoklora v primerjavi s ZM, ki vsebuje v spodnjem horizontu tudi kalcit.

Preglednica 1: Minerali v tleh ZM in SM.

lokacija	globinski vzorec tal [cm]	kremen	muskovit/illit	albit	glineni minerali		kalcit
					montmorillonit	klinoklor	
SM	0–20	✓	✓	✓	✓	✓	✗
	20–40	✓	✓	✓	✓	✓	✗
ZM	0–20	✓	✓	✓	✗	✗	✗
	20–40	✓	✓	✓	✗	✓	✓

Tudi geokemične raziskave tal kažejo, da je vsebnost glavnih elementov precej podobna na obeh legah, a z nekaj razlikami (preglednica 2): tla ZM so obogatena z MgO in CaO ter imajo manj P_2O_5 kot tla SM. Ti rezultati so skladni z ugotovitvijo mineraloške analize, ki kaže na vsebnost karbonatov v tleh ZM.

Preglednica 2: Koncentracije glavnih elementov v tleh ZM in SM (vrednosti v %).

lokacija	globinski vzorec tal [cm]	SiO_2	Al_2O_3	Fe_2O_3	MgO	CaO	Na_2O	K_2O	TiO_2	P_2O_5	MnO	LOI
SM	0–40	58,5	14,8	6,2	1,4	1,2	0,9	2,8	0,7	0,19	0,18	13,0
ZM	0–40	60,3	15,8	6,7	1,7	1,7	0,9	2,8	0,8	0,13	0,21	8,9

3.5 Podnebne značilnosti

Vipavska dolina ima svojevrstno prehodno podnebje, ki predstavlja mešanico mediteranskih in celinskih vplivov. Sicer zmerno podnebje v dolini pogosto prekinja močan severovzhodni veter, imenovan burja, ki lahko doseže hitrost 200 km/h (npr. Mihevc 1997). Letna količina padavin v Vipavski dolini je med 1400 in 1700 mm (ARSO 2015). Glavnina padavin je jeseni in spomladi, snežne padavine so redke. V drugi polovici julija in v avgustu je običajno suho obdobje z neenakomerno razporejenimi kratkotrajnimi plohami in nalivi, ki jim sledijo daljša obdobja z malo padavinami, višjimi temperaturami in vetrom. Leta 2008 je količina padavin znašala 1601 mm, tj. 110 % povprečja v obdobju 1961–1990, povprečna letna temperatura zraka je bila 13 °C (slika 6; ARSO 2015). Pozimi se je povprečna dnevna temperatura spustila pod 0 °C za šest dni, poleti pa je dnevno povprečje doseglo do 27 °C (ARSO 2015). Sončno obsevanje je trajalo 2136 h/leto, kar je 101 % povprečja v obdobju 1961–1990 (ARSO 2015).

Znotraj vinograda se mikroklima razlikuje. Lega ZM je deležna več sončnega obsevanja, a je bolj izpostavljena burji. Lega SM je deležna manj sončnega obsevanja in je bolj podvržena zmrzali, a je manj izpostavljena burji.

Slika 6: Povprečna temperatura zraka (linije) in mesečna količina padavin v letu 2008 (vir podatkov: ARSO 2015).
Glej angleški del prispevka.

3.6 Antropogeni parametri

Vinograd Lončarjevec je zasajen s 3500 trsi, od tega je 800 trsov sorte malvazija, sajenih aprila 1993, na kordonski gojitveni obliki Casarsa. Medtrsna razdalja je 2,2 m in medvrstna razdalja je 3,0 m. Vrste potekajo v smeri severovzhod–jugozahod. Sadilni material, cepiči in podlaga trsov (selekcija Oppenheim 4) sta enaka na obeh legah. Poreklo sadilnega materiala je trsnica Vrhpolje pri Vipavi.

3.7 Grozdje in vino

Rezultati analiz rodnosti trsov in kakovosti grozdja in vina so prikazani v preglednici 3.

Preglednica 3: Parametri rodnosti trsov in kakovosti grozdja in vin.

	parametri	ZM	SM	statistična značilnost (%)
rodnost trsov	število grozdov na trs	19,4 ± 3,1	18,4 ± 4,8	70,8
	masa 10 naključnih grozdov na trsu [g]	1886 ± 241	1970 ± 258	61,2
	skupna masa grozdja na trs [g]	3600 ± 400	3700 ± 1.400	88,6
	masa 100 naključnih jagod na trsu [g]	256,9 ± 10	262,5 ± 10.1	40,4
kakovost grozdja	sladkor [öe]	83 ± 8	77 ± 3	18,2
	skupna kislina [g/l]	10,3 ± 1,4	12,0 ± 1,5	10,4
	pH	3,20 ± 0,10	3,09 ± 0,03	9,3
kakovost vina	alkohol [vol. %]	10,9	10,4	
	reducirajoči sladkor [g/l]	0,9	1,2	
	skupna kislina [g/l]	10,3	11,3	
	pH	3,22	3,10	

Trsi SM in ZM so imeli primerljivo število grozdov na trs in primerljivo skupno maso grozdja na trs (slika 7). Povprečna masa 100 jagod je bila večja na legi SM (slika 7). Razlike sicer niso bile statistično značilne.

Slika 7: Whisker diagrami za parametre rodnosti trsov.
Glej angleški del prispevka.

Povprečna koncentracija sladkorja in pH je bila višja, skupna kislina pa nižja v grozdju ZM (slika 8). Samo razlike v skupni kislini in vrednosti pH so statistično značilne na ravni zaupanja 10,4 % oziroma 9,3 %.

Slika 8: Whisker diagrami za parameter kakovosti grozdja.
Glej angleški del prispevka.

Vino ZM je imelo več alkohola, višji pH in nižjo skupno kislino. Statistične značilnosti razlik sicer ni moč oceniti, ker je bilo iz vsake lege pridelano le eno vino.

4 Razprava

Kljub zelo podobnim geološkim, pedološkim in makroklimatskim pogojem se je kakovost grozdja na legah ZM in SM razlikovala, predvsem v vsebnosti skupnih kislin in pH v prsti/tleh. Skupna kislina v vinu vpliva na senzorično zaznavanje kislosti. Čeprav je bila vinifikacija izvedena na samo enem vzorcu za vsako lego, razlike v skupni kislini in vrednosti pH v vinih potrjujejo razlike ugotovljene v grozdnem soku.

V določenem letu je skupna kislina v moštu odvisna predvsem od geologije, tal in podnebja, vključujoč vlažnost in prepustnost tal, vzorce padavin in temperaturo. Glede na to, da imata legi ZM in SM identično makroklimo in geološko podlago, so značilne razlike v vinih pogojene z različno sestavo tal (1), drenažo (2) in mikroklimo (3), kar je neposredno povezano z geomorfno pozicijo obeh leg.

1. Globina tal ZM (20 cm do 2 m) dovoljuje temeljito rigolanje in homogenizacijo hranil v tleh, s čimer lahko pojasnimo nekoliko višjo vsebnost CaO in MgO v primerjavi s tlemi SM. V do 5 m debelih tleh SM rigolanje ni doseglo globljih horizontov, zato CaO in MgO nista bila reciklirana iz globljih delov.
2. Lega ZM na strmem pobočju dovoljuje precej boljšo drenažo. To je deloma tudi rezultat mineraloških razlik; tla ZM imajo nižjo vsebnost glinenih mineralov, saj se le-ti izpirajo v globlje horizonte tal, premeščajo po pobočju navzdol in akumulirajo v tleh SM. Gline imajo večjo sposobnost zadrževanja vode in zavirajo odvodnjavanje. Ker ima blago do srednje pomanjkanje vode pozitiven efekt na vsebnost kislin v grozdju in vinu ter na senzorične značilnosti vina (npr. Zsofi s sodelavci 2011), je dobra drenaža bistvena za boljšo kakovost vina.
3. Pobočje s svojim naklonom vpliva na delež prejetega sončnega obsevanja (Huggett 2006). Lega ZM prejme več sončnega obsevanja, ima višjo stopnjo evapotranspiracije in je manj podvržena zmrzali. Višja vsebnost glinenih mineralov v tleh SM prispeva tudi k hitrejši izgubi toplote, kar se odraža v vsebnosti kislin v grozdju in vinu (cf. Huggett 2006).

5 Sklep

Leta 2008 smo pridelali dve vini sorte malvazija iz dveh različnih leg znotraj istega vinograda v Vipavski dolini, ki sta na terasiranem pobočju in na dnu manjše doline. Z enakimi vinogradniškimi in vinarskimi tehnikami pridelave sta bili kakovost grozdja in vina iz obeh leg različni. Glede na to, da sta geološka podlaga in makroklima v obravnavanem vinogradu enotni, so značilne razlike v grozdju in vinu rezultat različne sestave tal, drenaže in mikroklime. Omenjeni parametri so v neposredni zvezi z različno geomorfno lego trsov. Geomorfna pozicija vinograda in tudi posameznih trsov vinske trte znotraj posameznega vinograda torej vplivata na kakovost vina.

6 Literatura

Glej angleški del prispevka.