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Neglected cultivars for the Mtskheta-Mtianeti region (East Georgia): ampelography, phenology, and agro-climatology

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Summary

Georgia is an important source of grapevine intra-specific variability for viticulture. This biodiversity can be a suitable tool to face the challenge of climate change. Nevertheless, it is important to take into account the interaction between the interest genotype and the local environment, whose climate is changing due to global heating. In this work, we put in relation the phenotypic behavior of some neglected Georgian cultivars ('Tabidziseuli', 'Daisi', 'Qvelouri', 'Bazaleturi Colikouri') from the Mtskheta-Mtianeti Georgian region to the agro-climatology of the region itself. The phenological phases and the vegetation length of these four grape varieties were described, as well as their principal ampelographic characters. The impact of global heating on the agro-climatology of the Mtskheta-Mtianeti region has also been established, by comparing the sum of active temperatures (>10°C) of multi-years (1948-2017) with those calculated for the future scenario (2020-2050, temperature increase by 2°C). Based on this comparison, three agro-climatic zones have been confirmed within the region: dry subtropical, mountain and high mountain. The scenario of temperature increase by 2°C in the next three decades will cause the sum of active temperatures to reach 3900-4000°C in the dry subtropical zone, 3400-3500°C in the mountain zone and 1900-2000°C in the high mountain zone. Considering the vegetation length of the cultivars analyzed, it can be expected a shift of the most suitable sites for viticulture from the dry subtropical zone to the mountain area. High mountain seems not to be suitable for the cultivation of the studied cultivars. Given this environmental variability within the region, the increase in temperature will not suppress viticulture in Mtskheta-Mtianeti, if the real temperature does not exceed the level predicted by scenario.

Keywords

climate change, active temperature, vegetation period, cultivar valorisation, grapevine, intra-specific variability

Introduction

Climate change impacts agriculture, viticulture, and wine industry. Environmental resources such as climate and soil conditions affect yield and quality of the grapes (Van Leeuwen and Destrac-Irvine, 2017). Warmer air temperature during wintertime could lead the budburst to occur earlier in the growing season, thus exposing grapevines to the risk of spring frosts (Dinu *et al.*, 2021a). In the summer, the increase of temperature could shift the ripening phase to warmer periods, thus influencing grape composition (Jones and Davis, 2000) and summer stresses could block the ripening process (Rosas *et al.*, 2022). In addition, water scarcity in the soil increases water deficit in the plants, which will reduce yield and modify fruit quality (Pillet *et al.*, 2016). Due to the importance of the wine sector around the world, over recent years there has been an increase in work to study the impact of climate change on viticulture.

Climate change is becoming evident also in Georgia, especially in the east part of the Country; where a temperature increase of 0.4-0.5°C in 30 years was observed (in the same period, in west Georgia this temperature shift was 0.2°C) (Tavartkiladze *et al.*, 2012). Mariani *et al.* (2012) reported 1987-1988 as the breakpoint years for the increase of temperature on the European continent. However, it is worth noticing that only in 1994 Georgia faced a significant rise in temperatures. This delay between Georgia and Western Europe can be the effect of the progressive dilution of the Oceanic signal as it moves into the European continent (Cola *et al.*, 2017).

A few studies have focused on the risks for agriculture in general, and for viticulture in particular, in Georgia (Meladze and Meladze, 2005, 2013a). Georgia is characterized by vine-growing regions having different climatic conditions. Depending on the region, climate change may have different implications on grapevine phenology. For instance, working with the Georgian cultivar 'Rkatsiteli', Cola *et al.* (2017) found that at higher altitudes (750-1000 m) new more favorable

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thermal conditions for the advance of veraison can be found; on the other hand, at lower altitudes (250-500 m), the advance of veraison was partially depleted by the increase of stress conditions for the plants. In view of a probable exacerbation of the effects of climate change in viticulture, the high intra-specific variability in the plant phenology among Georgian germplasm can be a useful resource for vine growers (Sargolzaei *et al.*, 2021). Indeed, selecting varieties with a delayed budburst could represent an avoidance mechanism against spring frosts (Dinu *et al.*, 2021a). Similarly, considering the strong increase of temperatures above the optimal range (24–26°C) for grape ripening during summer (Cola *et al.*, 2020), late-ripening cultivars could ensure the grapes to ripen under relatively cooler conditions. Maghradze *et al.* (2012) made a comparison between 134 Georgian varieties with 'Chardonnay' and 'Cabernet Sauvignon' grown all in the same area (northern Italy). They found a relatively late phenology for the former. Amongst several Georgian cultivars, the latest ripening ones are 'Saperavi Meskhuri', 'Ghrubela' and 'Shavtita' (end of September), with 'Gorula' the very latest ripening one (beginning of October) (Maghradze *et al.*, 2014). Nevertheless, as suggested by Abashidze *et al.* (2015), a deeper technological characterization of the winemaking potential for at least the most suitable cultivars for cultivation should also be considered.

Georgia is a precious source of grapevine biodiversity. Genotyping the Georgian germplasm by both nuclear SSR (simple sequence repeat) and SNPs (single nucleotide polymorphisms) molecular markers (Imazio *et al.*, 2013; De Lorenzis *et al.*, 2015) confirmed this evidence. Moreover, the uniqueness of this germplasm, being Georgia the center for grapevine (*Vitis vinifera* L.) domestication (McGovern, 2003; McGovern *et al.*, 2017), makes Georgian cultivars very attractive for further investigations. However, many minor cultivars remain poorly studied and their knowledge is not widely accessible to researchers, being often reported in local publications written in Georgian (Tsetsvadze, 1987; Ujmajuridze *et al.*, 2018).

Considering the importance of Georgia as a source of intraspecific biodiversity for viticulture, in this work, we aim at describing four neglected Georgian cultivars in order to enlarge the ampelographic platform of the Mtskheta-Mtianeti region. The agro-climatic characteristics of the different areas (dry subtropical, mountain, high mountain) of this region have been analyzed, also in view of a possible scenario of climate change. This approach could be a useful support to prospect the possible interaction among these minor genotypes with the local environments.

Material and Methods

Experimental site

The research was conducted at the Georgian national ampelographic collection 'Jigaura Solomon Cholokashvili' (FAO international code GEO038), belonging to the scientific investigation center of the Georgian Ministry of Agriculture. This collection includes 450 Georgian cultivars (*Vitis vinifera* ssp. *sativa*), more than 300 foreign varieties (*Vitis vinifera* ssp. *sativa*), about 100 wild grapevine genotypes (*V. vinifera* ssp. *sylvestris*) and the basic callus material of clones and varieties. Twenty plants are kept for each genotype.

The vineyard is situated in the Mtskheta-Mtianeti region, East Georgia, to the right side of the river Tedzami (Latitude 41.55, Longitude 44.46, Elevation 586 m a.s.l.). The vineyard is planted in a plain area with a typical alluvial carbonated deep soil, high skeleton and middle to heavy clay texture. Limestone is about 18-20% and its percentage increases with depth, organic matter is 1.4-1.6%. The soil is poor in nitrogen and phosphorus, and it has a medium content in potassium. Details of the soil analyses are available in Supplementary Information (Tables SI1 and SI2). This macro-area is characterized by a continental climate with cold winter and hot summer. The mean annual temperature is 10.8°C, the hottest months are July and August with 22°C, the sum of active temperatures by the altitudinal gradient varies between 3350°-1630°C, the mean humidity of the air is 60-62% and precipitations during the vegetation period range between 400 and 510 mm.

The experimental vineyard was planted in 2008. The soil is managed with natural grass cover. The vineyard is equipped by a drip irrigation system. Plants are spaced by 2.35 m (interrow) and 1.25 m (intrarow), with a plant density of about 3400 plants·ha^{-1}. The training system is a double cane without spur. Jighaura's collection rows of vineyard are directed from west to east, because of the wind direction (Mamasakhlisashvili and Ujmajuridze, 2020; Dinu *et al.*, 2021b).

Experimental design

Four grape cultivars were considered: 'Tabidziseuli' is reported as a cross 'Sapena' × 'Khikhvi', but it is not included in the *Vitis* International Variety Catalogue (*V*IVC); 'Daisi' ('Kukan Cibili' × 'Saperavi' – with mutations induced by radio-genetics) has the variety number *V*IVC – 16477; the two Imeretian cultivars 'Qvelouri' and 'Bazaleturi Colikouri' (synonyms "Bazaleturi", "Mtsvane Colikouri") have 6591 and 1053 *V*IVC code, respectively. All these varieties are rare cultivars and have limited distribution. Furthermore, 'Qvelouri' and 'Bazaleturi Colikouri' are spread in the form of single plants on homestead plots in the Imereti region, while 'Daisi' and 'Tabidziseuli' (selected new varieties) are preserved only in the Jighaura Experimental collection.

Twelve SSR markers were used for genotyping: the nine proposed as common grape markers for international use within the framework of the Grapegen06 European project (VVS2, VVMD5, VVMD7, VVMD25, VVMD27, VVMD28, VVMD32, VrZAG62, VrZAG79) (Maul *et al.* 2012), plus VMC6E1, VMC6F1, VMC6G1 (Crespan, 2003), and VMCNG4b9 (Welter *et al.*, 2007). The SSR analyses were performed following the protocol detailed in Migliaro *et al.*, 2013; two internationally required SSR markers (VVMD25 and VVMD32) were also added and the set of 12 SSR markers were analyzed by two multiplex PCRs using fluorescent primers and an ABI3130xl genetic analyzer (Applied Biosystems, Foster City, CA, USA). The presence of PCR products was assessed by electrophoresis in a 1.5% agarose gel and quantified by comparison with a MassRuler DNA ladder mix (Thermo Fisher Scientific, Waltham, MA, USA). PCR products (0.5 µL) were mixed with 9.35 µL of formamide and 0.15 µL of the GeneScan™ 500 LIZ Size Standard (Life Tech, Carlsbad, CA, USA). Capillary electrophoresis was conducted in an ABI 3130xl Genetic Analyzer (Life Tech, CA, USA). Allele calling was performed with GeneMapper 5.0, using the 500 LIZ size standard as an internal ladder and a homemade bin set built with reference varieties. Allele sizes were recorded in bp using the *V*IVC allele sizing, and genotypes showing a single peak at a given locus were considered homozygous. Identifications were performed by comparing the obtained SSR profiles with the CREA – Research Centre for Viticulture and Enology (which currently contains about 8000 unique profiles, and is constantly updated), literature information, and the *V*IVC public database.

Ampelographic description of each cultivar was carried out based on the OIV recommendations (OIV, 1984). We used 47 descriptors: three of them for the young shoot, five for the shoot, two for the young (4th) leaf, 15 for the mature leaf, one for the flowers, one for the woody shoot, six for the bunch, eight for the berry, and six elements of productivity. In Table 2, each descriptor is reported together with its specific OIV code. Cultivar phenology was described according to the BBCH scale (Lorenz *et al.*, 1995) following the COST FA-1103 project recommendations (Rustioni *et al.*, 2014). Phenology was recorded during three consecutive years: 2018, 2019 and 2020.

Meteorological data were obtained from the Institute of hydrometeorology of the Georgian Technical University and from the Georgian National Environmental Agency. Starting from 1948, about 70 years of meteorological data were obtained to be processed and statistically analyzed. Data came from different meteorological stations belonging to different areas of the region: dry subtropical zone (Mtskheta – Elevation 460 m a.s.l.); mountains (Dusheti – Elevation 922 m a.s.l.); high mountains (Kazbegi – Elevation 1744 m a.s.l.).

The date of air temperature transition above and below 10°C in agro-climatic zones was calculated by means of corresponding equations:

- y= -2.4 × +79 (in spring);
- y= 3.2 × -33 (in autumn);
- y – Date of air temperature transition above and below 10°C in spring and autumn;
- x – Sum of mean temperatures of two months in spring and autumn (in spring period – February and March, or March and April; in autumn – September and October, or October and November); the mean temperature of the first month must be less than 10°C, and that of the second month – more than 10°C (Meladze *et al.*, 2016; Meladze and Meladze, 2020).

The impact of climate change on the agroclimatic indexes between 1948 and 2017 was calculated from trend equations.

The data of the future scenario (temperature increase by 2°C for the period of 2020-2050) which were received according to the regional climate model RegCM-4 and by the A1 scenario of social-economic development have been processed. This model was approved and used in the third Georgian national message of the climate change frame convention (The Third National Communication Climate Change of Georgia, 2015; Meladze and Meladze, 2017).

The forecasting sums of active temperatures (>10°C, in case of increase by 2°C), for distinguishing the agro-climatic zones of grapevine distribution, were calculated according to our equation:

- n = 0.036 h + 38 (for the calculation of date of the temperature above 10°C);
- T = -44.254 n -0.150 h + 6742 (for the calculation of sums of active temperatures (>10°C));
- n – Date of the establishment of the mean daily temperature of air above 10°C; *i.e.* the number of days beginning from the 1st of February till the date of temperature establishment at 10°C;
- h – Height above sea level (m);
- T – Sum of active (>10°C) temperatures.

Hydrothermal coefficients were calculated following the method described in Meladze (2008).

Results and Discussion

Meteorological data

The map of the Mtskheta-Mtianeti region is available in supplementary materials (Figure SI1). Three agro-climatic zones have been distinguished in the Mtskheta-Mtianeti region, based on the altitudinal gradient, as already suggested by Arveladze and Meladze (2011), Meladze and Meladze (2013b, 2018).

During the last 70 years, the climatic conditions of the Mtskheta-Mtianeti region underwent significant modifications. For example, Fig. 1 reports the trend of the sums of active temperatures (>10°C) in the dry subtropical zone, showing an evident increase. The impact of climate change (1948-2017) on the agroclimatic indexes produced an increase of the sum of active temperatures in the dry subtropical zone of 289°C, in the mountain zone of 216°C and in the high mountain zone of 286°C. These increases have been already described for the different zones of the region by Meladze and Meladze (2021). In other regions of Georgia, meteorological data taken from 1949 to 2008 revealed a considerable increase in air temperatures in the western humid subtropical region of Guria (20°C) and, even more, in the eastern mountainous and high mountainous Akhmeta Municipality of the Kakheti region (340°C and 210°C, respectively) (Meladze *et al.*, 2016). These trends confirm that the impact of global warming is not spatially homogeneous in Georgia, being the mountainous and high mountainous zones the most affected. Similar results were obtained in other countries. Alikadic *et al.* (2019) showed that, in the mountainous province Trentino (Italy), the higher the altitudes the more pronounced the effects of temperature increase are expected nowadays and in the future scenarios. Indeed, phenological advance due to climate change is more marked for varieties grown at higher altitudes. Still in Trentino, Caffarra and Eccel (2011) produced for different levels of altitude a pheno-climatic simulation (budbreak, flowering and veraison) of 'Chardonnay' according to two different future climate scenarios. They found an advance for all the

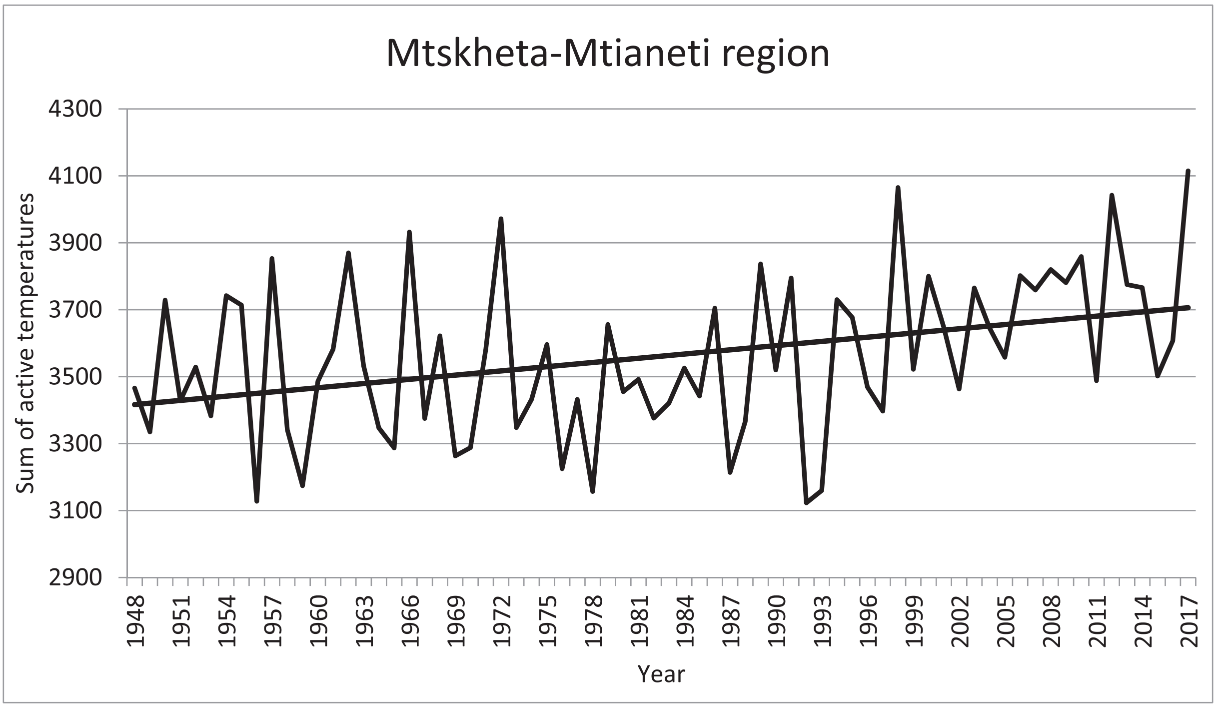

Fig. 1: Dynamics of the sum of active temperatures (>10°C) in the dry subtropical zone (Mtskheta).

phenophases, but more pronounced at higher elevations. Recently, Rodrigues *et al.* (2022) obtained similar predictions for 'Touriga Nacional' in the Dão wine region, Portugal.

In the supplementary materials (Table SI2) it is possible to find a comparison between the climatic indexes calculated on the two periods 1948-1982 and 1983-2017 in the Mtskheta-Mtianeti region.

Table 1 shows that currently the air temperature increases above 10°C, becoming active for grapevine growth, in the dry subtropical zone of Mtskheta-Mtianeti on April 8, and that it decreases below 10°C in October 26 (Table 1A). Considering a scenario of temperature increase of 2°C, these dates will change to March 31 and November 7 respectively (Table 1B). Thus, the increase of temperature by 2°C in spring will cause its rise above 10°C 8 days earlier, and, in autumn, the decrease of the temperature below 10°C will happen 12 days later, with respect to the last 70 years average. Accordingly, the vegetation period in the given zone becomes 20 days longer. In case of prolongation of the vegetation period of 20 days in the dry subtropical zone, in the future scenario (2020-2049), the increase of the sum of active temperatures (>10°C) will be 444°C. For the western humid subtropical region of Guria, Meladze *et al.* (2016) projected an increase in the sum of active temperatures of 220 °C in case of temperature increase by 1°C for the period of 2020-2030. The sum of atmospheric precipitations in the dry subtropical zone of Mtskheta-Mtianeti decreased by 3 mm from 1948 to 2017 (data not shown), while in Guria it decreased by 139 mm from 1949 to 2008.

Table 1: The agro-climatic characteristics of dry subtropical, mountain and high mountain zones of the region Mtskheta-Mtianeti. A: data elaboration of the period 1948-2017; B: data calculated for future scenario (2020-2049), in case of air temperature increase by 2°C

	Zone	Data of transition air temperature >10°C	Data of transition air temperature <10°C	Duration of the vegetation (days)	Sum of active temperatures (>10°C)	Sum of precipitations (mm), IV-X	HTC (IV-X)	Sum of active temperatures (>10°C) VI-VIII	Sum of precipitations (mm), VI-VIII	HTC (VI-VIII)
A Period 1948-2017	Dry subtropical	April 8	October 26	201	3542	403	1.1	1980	178	0.9
	Mountain	April 18	October 20	185	3095	509	1.6	1792	214	1.2
	High mountain	May 21	September 22	124	1628	476	3.0	1288	356	2.7
B Prediction (increase of temperature by 2°C)	Dry subtropical	March 31	November 7	221	3986					
	Mountain	April 9	October 31	205	3581					
	High mountain	May 12	October 1	142	2088					

HTC = hydrothermal coefficients

In the mountain zone of the Mtskheta-Mtianeti region, the increase of air active temperature above 10°C in spring currently happen on April 18 (Table 1A), while, considering a rise of temperature by 2°C, an advance of 9 days should be expected (Table 1B). In autumn, the decrease of temperature below 10°C currently should be expected on October 20, while, in the future scenario, a delay of 11 days is estimated. Accordingly, in the mountain zone of the region the vegetation period will be prolonged by 20 days (from 185 to 205 days). Following the future scenario (rise by 2°C), an increase of sum of the active temperatures of 486°C could be expected. For the eastern mountain region of Kakheti, Meladze *et al.* (2016) projected an increase in the sum of active temperatures of 460°C in case of temperature increase by 2°C for the period of 2020-2030. The sum of atmospheric precipitations in the mountain zone of Mtskheta-Mtianeti decreased by 19 mm from 1948 to 2017 (data not shown), while in the mountain region of Kakheti it decreased by 15 mm from 1949 to 2008.

The global warming also influences the agro-climatic characteristics of the high mountain zone. Currently, the increase of air temperature above 10°C in spring is observed on April 21, while in autumn the decrease of the temperature below 10°C happens on September 22 (Table 1). Considering a future scenario characterized by an increase of temperature of 2°C, an advance of 9 days in the beginning of active temperatures for vine growth in spring, and a delay of 9 days in the end of the vegetation period (temperatures below 10°C) should be expected. Thus, the vegetation period in the high mountain zone will change, being prolonged by 18 days. Therefore, also the sum of the active temperatures could rise, reaching 460°C. These data agree with the results obtained by Meladze (2008). For the eastern high mountain region of Kakheti, Meladze *et al.* (2016) projected an increase in the sum of active temperatures of 450°C in case of temperature increase by 2°C for the period of 2020-2030. The sum of atmospheric precipitations in the high mountain zone of Mtskheta-Mtianeti decreased by 113 mm from 1948 to 2017 (data not shown), while in the mountain region of Kakheti it decreased by 26 mm from 1949 to 2008.

Thus, if the tendency of enhancement of the active temperatures sum continues in future, the sum of temperatures in the dry subtropical zone 4-5 decades later may reach 3900-4000°C or more; in mountain zone – 3400-3500°C and more; and in the high mountain zone – 1900-2000°C and more.

In general, it should be taken into consideration that the temperature rise will be probably coupled with the tendency of precipitation decrease, as already mentioned above. Therefore, it will be possible that additional water supply will be necessary, especially in the dry sub-tropical zone, during the hottest period (June-August) in order not to affect detrimentally vine performance and grape composition. Similar needs have also been reported for other areas worldwide. In California, Ayars *et al.* (2017) showed that severe water deficit on 'Cabernet Sauvignon' grapes three weeks after fruit set led to loss of yield without improving overall wine quality. Aris *et al.* (2022) investigated the effect of water deficit on the anthocyanin composition in 'Cabernet Sauvignon' grapes, this time grown in Chile. At harvest, plant water status did not induce a greater accumulation of one or another type of anthocyanin, whose proportions influence the colour of the resulting wine. Even though rainfed watering regime for grapevine would not be economically sustainable, this tendency of precipitation decrease goes well with the deficit irrigation strategy. Deficit irrigation consists of applying water rates to replace only part of the potential vine evapotranspiration during the whole season or during just some phenological periods previously established (Pérez-Álvarez *et al.*, 2021). In arid and semi-arid regions, such as those with a Mediterranean climate, deficit irrigation is a promising tool to transmit the maximum oenological potential from grapes to the final wine. For cultivar 'Bobal', Lizama *et al.* (2021) demonstrated that deficit irrigation positively affected must astringency and possibly the bitterness sensation of the wine. Additionally, the grapes from the deficit irrigation strategy had some aromatic compounds increased with respect to those rainfed.

Grapevine genotyping, ampelography and phenology

The molecular analyses were performed on the four grapevine samples and the identification results with the SSR data are summarized in Table SI3 (supplementary information).

'Qvelouri' and 'Bazaleturi Colikouri' were identified through the *V*IVC website molecular database.

The *V*IVC prime name of 'Qvelouri' is 'Kvelouri' and matches by molecular and morphological analyses with 'Shava' black variety reported in Lacombe et. al., 2013.

'Bazaleturi Colikouri' is characterized by functionally female flowers. This trait is considered as ancestral and related to *Vitis vinifera* domestication, however it could be inherited through segregation by sexual reproduction, given that cultivated grapevines frequently carry a female allele (Hf), while homozygous hermaphroditic vines (HH) are rare (Fechter *et al.* 2012).

Some accessions, being true-to-type because of ampelographic descriptors, turned out to be critical after comparison of their SSR profiles with literature data. 'Tabidziseuli' was classified as questionable, because the SSR profile corresponds to 'Kumsi Tetri' (*V*IVC code 6556) stored in the CREA-germplasm collection of Conegliano. No SSR data from literature are available; further observations are necessary to check the authenticity of this variety, with respect to the available ampelographic description, provided that the most likely scenario was the synonymy between 'Tabidziseuli ' and 'Kumsi Tetri'.

'Daisi' is a black variety according to *V*IVC, but it is lacking the SSR profile; anyway, we can confirm the true-to-typeness of the variety. Based on morphology in the present paper we provide the microsatellite fingerprinting profile. Moreover, our data show that it could be parent-offspring related with 'Saperavi', because they share at least one allele per locus for all 12 SSR markers, evaluating the hypothesis reported in literature as a cross of 'Kukan Tsibil' × 'Saperavi'.

The varieties 'Tabidziseuli', 'Daisi', 'Qvelouri', 'Bazaleturi Colikouri' are rare and neglected cultivars in Georgia. The variety 'Tabidziseuli' is internationally described for the first time in this paper, while the here reported description of 'Qvelouri', 'Daisi' and 'Bazaleturi Colikouri' corresponds to the descriptions reported in literature. 'Tabidziseuli', 'Bazaleturi Colikouri' and 'Daisi' are preserved only in collection with 20 plants each. Single plants of 'Qvelouri' can be found in homestead vineyards in the Imereti region, and 20 plants of this variety are also preserved in the collection. The new knowledge of these minor varieties could improve the intraspecific biodiversity in the local vineyards, improving the agricultural resilience. Many efforts have been made internationally for minor cultivar valorisation (Rustioni *et al.*, 2019), with a special focus on Georgia due to the crucial role of this Country in the grapevine domestication (Sargolzaei *et al.*, 2021; Imazio *et al.*, 2013). Table 2 reports the ampelographic description of these grape varieties, and Fig. 2 shows the grape bunches of these varieties.

The phenology of each variety was recorded during three consecutive years (2018, 2019, and 2020). Fig. 3 summariz-

Table 2: Basic ampelographic characters and phenotyping trial of: 'Tabidziseuli', 'Daisi', 'Qvelouri' and 'Bazaleturi Colikouri'

	TABIDZISEULI	DAISI	QVELOURI	BAZALETURI COLIKOURI
Young Shoot				
OIV 001 – Opening of the shoot tip	5 – fully open	5 – fully open	5 – fully open	5 – fully open
OIV 003 – Intensity of anthocyanin coloration on prostrate hairs of the shoot tip	1 – none or very low	1 – none or very low	3 – low	3 – low
OIV 004 – Density of prostrate hairs on the shoot tip	5 – medium	1 – none or very low	5 – medium	7 – high
Shoot				
OIV 006 – Attitude (before tying)	3 – semi-erect	3 – semi-erect	3 – semi-erect	3 – semi-erect
OIV 007 – Color of the dorsal side of internodes	2 – green and red	2 – green and red	2 – green and red	2 – green and red
OIV 008 – Color of the ventral side of internodes	1 – green	1 – green	1 – green	1 – green
OIV 016 – Number of consecutive tendrils	1 – two or less	1 – two or less	1 – two or less	1 – two or less
OIV 155 – Fertility of basal buds (buds 1-3)	5 – medium	5 – medium	5 – medium	5 – medium
Young (4th) Leaf				
OIV 051 – Color of upper side of blade	3 – bronze	3 – bronze	3 – bronze	2 – yellow
OIV 053 – Density of prostrate hairs between main veins on lower side of blade	7 – high	1 – non or very low	9 – very high	9 – very high
Mature Leaf				
OIV 067 – Shape of blade	2 – wedge-shaped	2 – wedge-shaped	2 – wedge-shaped	1 – cordate
OIV 068 – Number of lobes	3 – five	2 – three	3 – five	2 – three
OIV 070 – Area of anthocyanin coloration of main veins on upper side of blade	1 – absent	3 – up to the 1st bifurcation	3 – up to the 1st bifurcation	1 – absent
OIV 072 – Goffering of blade	3 – weak	1 – absent or very weak	5 – medium	5 – medium
OIV 074 – Profile of blade in cross section	3 – involute	5 – twisted	5 – twisted	4 – revolute
OIV 075 – Blistering of upper side of blade	5 – medium	1 – absent or very weak	5 – medium	5 – medium
OIV 076 – Shape of teeth	3 – both sides convex	3 – both sides convex	3 – both sides convex	3 – both sides convex
OIV 079 – Degree of opening/overlapping of petiole sinus	3 – open	3 – open	7 – overlapped	3 – open
OIV 080 – Shape of base of petiole sinus	1 – U-shaped	2 – brace-shaped ({)	1 – V-shaped	1 – V-shaped
OIV 081-1 – Teeth in the petiole sinus	1 – absent	1 – absent	1 – absent	1 – absent
OIV 081-2 – Petiole sinus base limited by vein	1 – not limited	1 – not limited	1 – not limited	1 – not limited
OIV 083-2 – Teeth in the upper lateral sinuses	1 – absent	1 – absent	1 – absent	1 – absent
OIV 084 – Density of prostrate hairs between main veins on lower side of blade	7 – high	1 – non or very low	7 – high	7 – high
OIV 087 – Density of erect hairs on main veins on lower side of blade	1 – none or very low	1 – non or very low	1 – non or very low	1 – non or very low
OIV 094 – Depth of upper lateral sinuses	5 – medium	3 – shallow	5 – medium	3 – shallow

Table 2: Continued

	TABIDZISEULI	DAISI	QVELOURI	BAZALETURI COLIKOURI
Flower				
OIV 151 – Sexual organs	3 – fully developed stamens and fully developed gynoecium	3 – fully developed stamens and fully developed gynoecium	3 – fully developed stamens and fully developed gynoecium	4 – reflexed stamens and fully developed gynoecium
Woody Shoot				
OIV 103 – Main color	2 – brownish	2 – brownish	2 – brownish	2 – brownish
Bunch				
OIV 202 – Length (peduncle excluded)	3 – short	7 – long	3 – short	3 – short
OIV 203 – Width	3 – narrow	5 – medium	3 – narrow	3 – narrow
OIV 204 – Density	7 – dense	5 – medium	7 – dense	5 – medium
OIV 206 – Length of peduncle of primary bunch	3 – short	3 – short	3 – short	3 – short
OIV 208 – Shape	1 – cylindrical	3 – Funnel shaped	2 – conical	2 – conical
OIV 209 – Number of wings of the primary bunch	2 – 1-2 wings	2 – 1-2 wings	2 – 1-2 wings	2 – 1-2 wings
Berry				
OIV 220 – Length	3 – short	3 – short	3 – short	3 – short
OIV 221 – Width	3 – narrow	3 – narrow	3 – narrow	3 – narrow
OIV 223 – Shape	2 – globose	3 – broad ellipsoid	2 – globose	2 – globose
OIV 225 – Color of skin	1 – green yellow	6 – blue black	6 – blue black	1 – green yellow
OIV 231 – Intensity of flesh anthocyanin coloration	1 – non or very weak	3 – weak	1 – non or very weak	1 – non or very weak
OIV 235 – Firmness of flesh	2 – slightly firm	2 – slightly firm	2 – slightly firm	2 – slightly firm
OIV 236 – Particular flavor	1 – none	1 – none	1 – none	1 – none
OIV 241 – Formation of seeds	3 – complete	3 – complete	3 – complete	3 – complete
Elements Of Productivity				
OIV 502 – Single bunch weight	3 – low	3 – low	3 – low	3 – low
OIV 503 – Single berry weight	3 – low	3 – low	3 – low	3 – low
OIV 504 – Harvest (kg m^{-2})	5 – medium	5 – medium	5 – medium	5 – medium
OIV 505 Sugar content of must	7 – high	7 – high	7 – high	7 – high
OIV 506 Total acidity of must	5 – medium	5 – medium	5 – medium	5 – medium
OIV 508 Must pH	5 – medium	5 – medium	5 – medium	5 – medium

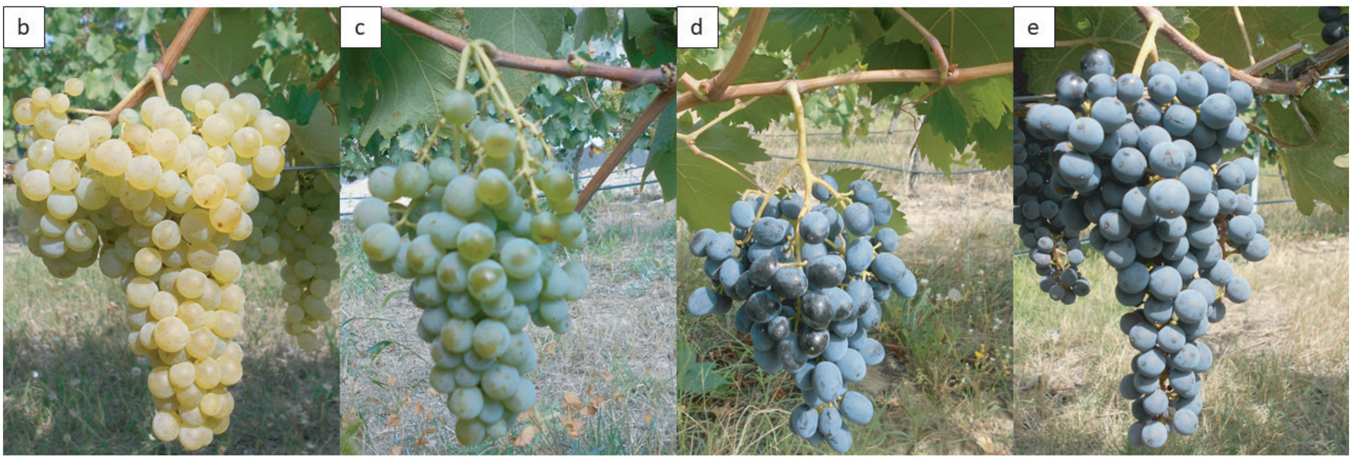

Fig. 2: Bunches of: ‘Tabidziseuli’ (b), ‘Bazaleturi Colikouri’ (c), ‘Daisi’ (d), ‘Qvelouri’ (e).

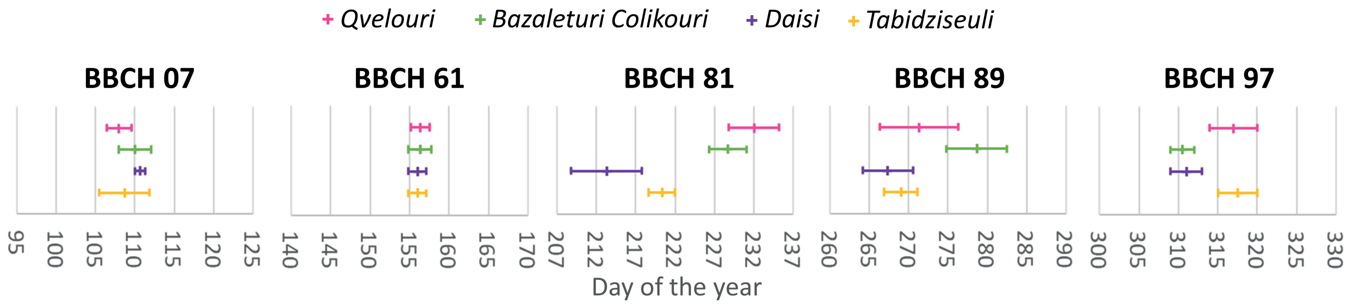

Fig. 3: Phenological phases of 'Qvelouri', 'Bazaleturi Colikouri', 'Daisi' and 'Tabidziseuli'. BBCH 07 = Beginning of bud burst: green shoot tips just visible; BBCH 61 = Beginning of flowering: 10% of flowerhoods fallen; BBCH 81 = Beginning of ripening: berries begin to soften; BBCH 89 = Berries ripe for harvest; BBCH 97 = End of leaf-fall. Bars indicates the standard error among the 3 years of observations.

es the obtained data. Bud burst occurred on April 18-25 for 'Tabidziseuli' and 'Daisi, and on April 20-22 for 'Qvelouri' and 'Bazaleturi Colikouri'. The vegetative growth of the first 15 leaves occurred between the 2nd of May and the 3rd of June. The flowering phase of the studied varieties began the 3rd of June and ended the 12th of June. The berry veraison (beginning of ripening) of each variety was different: in 'Tabidziseuli' it began the 5th of August, in 'Daisi' the 9th of August, in 'Qvelouri' the 12th of August, and in 'Bazaleturi Colikouri' the 20th of August. The fruit harvesting of 'Tabidziseuli' began the 22nd of September, of 'Daisi' the 28th of September, of 'Qvelouri' the 5th of October, and of 'Bazaleturi Colikouri' the 13th of October. The end of leaf fall of all the varieties happened in the period between November 10 and 15. The period between budburst and grape harvesting varied among cultivars: for 'Bazaleturi Colikouri' it was 169 days, for 'Qvelouri' 163 days, for 'Daisi' 157 days, and for 'Tabidziseuli' 160 days. The period between budburst and leaf fall varied among cultivars: for 'Bazaleturi Colikouri' it was 201 days, for 'Qvelouri' 209 days, for 'Daisi' 200 days, and for 'Tabidziseuli' 209 days.

Conclusions and perspectives

The region Mtskheta-Mtianeti is situated at 500-2000 m above sea level. Its landscape conditions are quite complex and variable. The northern part of the region (Kazbegi and part of Dusheti) is situated on the south slope of the Central Caucasus. The west border is surrounded by the region Shida Kartli, to the east it borders the regions of Kakheti and Kvemo Kartli.

The agriculture of Mtskheta-Mtianeti significantly contribute to the Georgian economy, providing high yield and quality productions (Meladze and Meladze, 2010; Gogitidze *et al.*, 2014). Nevertheless, further development of viticulture in the region is necessary to ensure the rise of social and economic levels of the population.

Within the region, three agro-climatic zones have been defined. The differences between these areas appear to be much bigger than the predicted impact of the climate change in each zone. Considering the vegetation length of the cultivars analysed and the agro-meteorological data provided, it could be expected a shift of the most suitable sites for viticulture from the dry subtropical zone to the mountain area. High mountain seems not to be suitable for the cultivation of the studied cultivars. Other varieties with a shorter vegetation period could be considered in perspective.

This environmental variability within the territory will ensure the possibility to maintain the viticulture production in Mtskheta-Mtianeti also in climatic conditions worsened by the increase in temperature. On the other side, the enlargement of the ampelographic platform should be considered as an important adaptation strategy, improving the system resilience through the variability among genotype × environmental interaction.

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Conflicts of interest

The authors declare that they do not have any conflicts of interest.

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