selekcijo klonov lahko pomembno vplivamo na kakovostne parametre grozdja, kar neposredno vpliva na slog vina. Hkrati lahko s pravilno odbiro klonov vinogradniško prakso prilagajmo spreminjajočim se podnebnim razmeram in ohranjamo tipičnost pridelanih vin.

Ključne besede: podnebne spremembe, klonska selekcija, monoterpeni, muškat, kakovost vina

INTRODUCTION

Muscats are a large group of *Vitis vinifera* L. grape varieties that share not only the common name but also the typical muscat aroma (Crespan and Milani, 2001). Within the Muscat family, there is a high genetic variability, mainly due to spontaneous natural mutations (OIV, 2017; van Leeuwen et al., 2019). In addition, there are a large number of synonyms and homonyms registered in the Vitis International Variety Catalogue (VIVC) (Maul, 2022). One of the most important wine varieties of the Muscat family, Muscat a petits grains blancs (MPG), is listed in the VIVC as Gelber Muskateller, Muscat blanc, Moscato bianco, Rumeni muškat, and other synonyms. The variety Muscato giallo is also listed in the VIVC and Goldmuskateller is mentioned as a synonym. The varieties MPG and M. giallo differ in phenological characteristics (e.g., ripening time), yield, and quality parameters (growth performance, yield, aroma profile, and sensory characteristics). The MPG variety ripens earlier, has larger clusters, and higher sugar and total acidity than M. giallo, as measured in must (Regner et al., 2015; Jaquerod et al., 2016). In addition, an important tool for improving vine parameters is clonal selection (Vujović et al., 2016; OIV, 2017). So far, several clones have been selected in France, Germany, Austria, and Italy for the variety MPG and in Italy and Germany for the variety M. giallo.

The specific and characteristic aroma profile of Muscat grapes and wines has been studied by several authors (Ribéreau-Gayon et al. 1975; Lanaridis et al., 2002), and the terpenes linalool, geraniol, nerol, α-terpineol, two furan oxides and two piran oxides of linalool have been identified as the main aroma compounds responsible for the typical Muscat aroma. Flamini et al. (2001) analysed the content of free and glycosidically bound monoterpenes in grapes of different Muscat varieties and confirmed that 78% of the samples with a similar genetic profile had similar aroma characteristics, although cultivation methods and environmental variables may influence each other. Moreover, among the varieties studied, a particularly high content of monoterpenes was found in those belonging to the M. giallo genetic profile, with the highest total linalool content (about 1.3 mg/kg of grapes) and the highest total diendiol I content (between 2.1 and 3.2 mg/kg of grapes). Monoterpenes also play an important role in the differentiation of wine varieties and their concentrations have a significant influence on the sensory quality of the wines produced (Rapp, 1998; Čuš et al., 2009).

The economic importance of Rumeni muškat (MPG variety) in Slovenia is significant, as it is grown on about 650 ha (RPGV, 2020). According to the literature, the different clones of Muscat varieties in Slovenia were not compared under the same experimental conditions. The choice of a suitable clone of a particular grape variety is definitely one of the prerequisites for producing high-quality grapes (Vujović et al., 2016) and wines with the desired chemical and sensory characteristics (van Leeuwen et al., 2013; Regner et al., 2021) and adaptation to climatic changes (van Leeuwen et al., 2019). Therefore, six MPG and five M. giallo clones originating from clonal selections in Austria, France, Germany and Italy were examined in the present study. The aim was to evaluate the viticultural and oenological characteristics of these clones and their potential use in different regions of Slovenia in the context of changing climatic conditions.

MATERIALS AND METHODS

Vineyard location and experimental design

Grapevine material of Muscat a Petits Grains Blancs (MPG) and Muscat giallo (Table 1) varieties was planted in a vineyard in the Vipava Valley in the Primorska wine region of western Slovenia with a sub-Mediterranean climate

Grape harvest and microvinifications

In the 2015, 2016 and 2017 vintages, approximately 25 kg of grapes per clone were harvested at the time of technical ripeness of the grapes, which was determined by measurements of total soluble solids (TSS) and total acids (TA). Grapes were destemmed using an Inox destemmer (Enoop, Vipava, Slovenia) and 0.25 g/L Suprarom product (25% ascorbic acid, 50% potassium metabisulfite, 25% tannins; Laffort, Bordeaux, France) was added to prevent oxidation of mash and must. The mash from each clone was pressed immediately after destemming using a 55-litre water bladder press with a maximum pressure of 1.5 bar (Lancman VSX 55, Gomark d.o.o., Vransko, Slovenia). The pressed must was collected in a 15-litre glass container/clone, and 50 mL of must was taken for analysis of total soluble solids (TSS), total acidity (TA), and pH. The must was left overnight at +4 °C for cold settling. The next day, the clear must was racked into 10-litre containers in the presence of N2 gas. After tempering to 18 °C, the must was inoculated with ADY *Saccharomyces cerevisiae* Uvaferm 228 (Lallemand, Montreal, QC, Canada) at a rate of 0.3 g/L without prior dehydration of the yeast. Fermentations were performed in a temperature-controlled room at 16 to 18 °C in one replicate per clone. The fermenting must was supplemented with the yeast nutrient Nutri start Org (0.3 g/L), corresponding to the addition of 30 mg yeast assimilable nitrogen (YAN)/L of must (Laffort, Bordeaux, France) at about 1/3 of fermentation, as determined by refractometric TSS measurements. The progress of fermentation was monitored by refractometric measurements of density in degrees Oechsle. All treatments fermented to a residual sugar content of 1.1-3.5 g/L as measured by an enzymatic robot (Mindray, BS -200, China). At the end of fermentation, a 5 to 6% aqueous solution of sulphurous anhydride was added at a level of 50 mg/L SO_2, and the wine was racked. The wines were bottled in 0.75-litre screw-cap bottles 8 to 10 weeks after the first racking and stored in the wine cellar at 12 °C.

Grape must and wine analysis

The TSS (Brix) in the must was determined using a digital refractometer WM -7 (Atago, Saitama, Japan). The pH value of must and wine were measured using MeterLab PHM 210 (Radiometer Analytical, Lyon, France). TA was determined by sodium hydroxide titration and the indicator bromothymol for colorimetric modification and expressed as g/L tartaric acid. Reducing sugars were quantified using an enzymatic robot (BS -200, Mindray, Nanshan, Shenzhen, China) and total dry matter using the method OIV-MA -AS2-03B (OIV, 2022). Alcohol content was measured using an Alcolyser Wine M alcohol meter (Anton Paar, Graz, Austria). Since the wines of the selected clones differ in the concentration of reducing sugars, their concentration was included in the calculation of potential (theoretical) alcohol.

Analyses of monoterpene alcohols

Analyses were performed by headspace solid-phase microextraction (HS-SPME) as described by Bavčar et al. (2011) using a gas chromatograph (GC, Agilent Technologies 7890A, Palo Alto, Santa Clara, CA, USA) coupled to MS (Agilent Technologies 5975C, Palo Alto, Santa Clara, CA, USA) and equipped with a Gerstel MPS autosampler (Gerstel, Mulhein an der Ruhr, Germany). Wine samples were diluted 1:4 with ultrapure MilliQ water. 4-nonanol was added to 5 ml of the diluted wine in an SPME vial, followed by the addition of 1.7 g NaCl. Compounds were separated on an INNOWax column (30 m x 0.25 mm, 0.25 µm film thickness; Agilent Technologies) connected to a deactivated 2 m x 0.25 mm fused silica guard column (Agilent Technologies). The ions used for the quantification of monoterpene alcohols and the method validation parameters are described elsewhere (Bavčar, 2011; Bavčar and Česnik, 2011).

Statistical analysis

Because there were not enough grapes to perform three replicates for each clone in each year, comparisons of viticultural and oenological parameters between clones were made with the combined sample of three years to form n = 3. Since vintage variation is accounted for, vintage is not separated as a separate variable. Therefore, all reported uncertainties of must and wine parameters are the standard deviation of three vintages for one clone. Analysis of variance (ANOVA) was performed using Statistica, version 12 (StatSoft, Tulsa, OK, USA). Means were separated and compared for significant differences at $P < 0.05$ using Fisher's LSD test. Principal component analysis (PCA) was performed using Statistica, version 12 (StatSoft, Tulsa, OK, USA) for data with scaled unit variance.

RESULTS AND DISCUSSION

Climatic conditions and phenological stages

Samples were collected in three growing seasons (from 2015 to 2017) that differed in GDD, average daily temperature and precipitation (Figures 1, 2), making our comparisons between clones and varieties robust. The average climatic parameters for the period from April 1 to September 30 for all three years were as follows: mean daily temperature 20.0 ± 0.9 °C, precipitation 624 ± 184 mm, and GDD value 1885 ± 92.

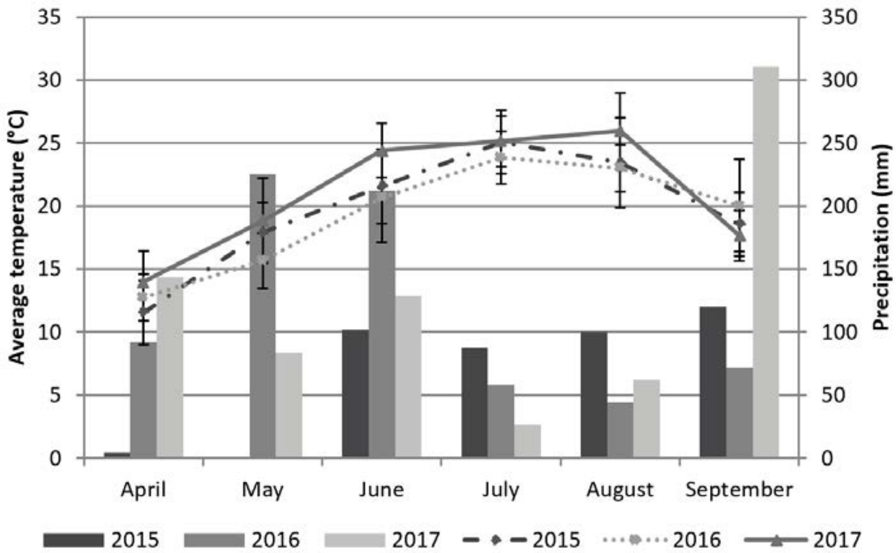

Figure 1. Average monthly precipitation (mm) - histograms and average temperatures (°C) from April 1 to September 30 at the Slap - Vipava Valley site for the 2015, 2016 and 2017 vintages

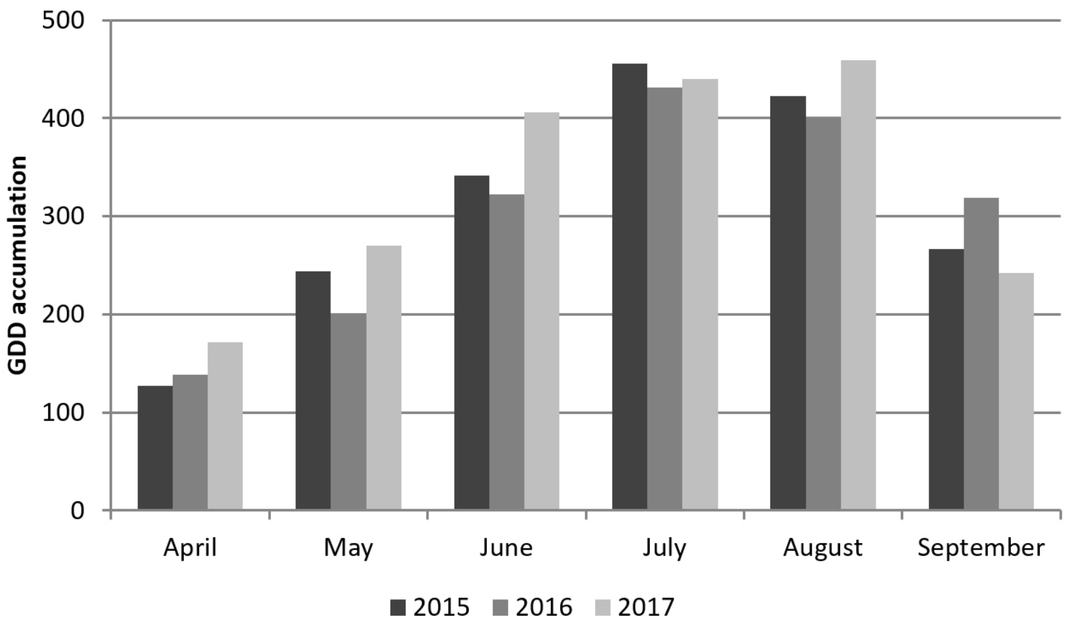

Figure 2. Growing degree days (GDD) by month for the vegetation periods 2015, 2016 and 2017 at the Slap - Vipava valley site

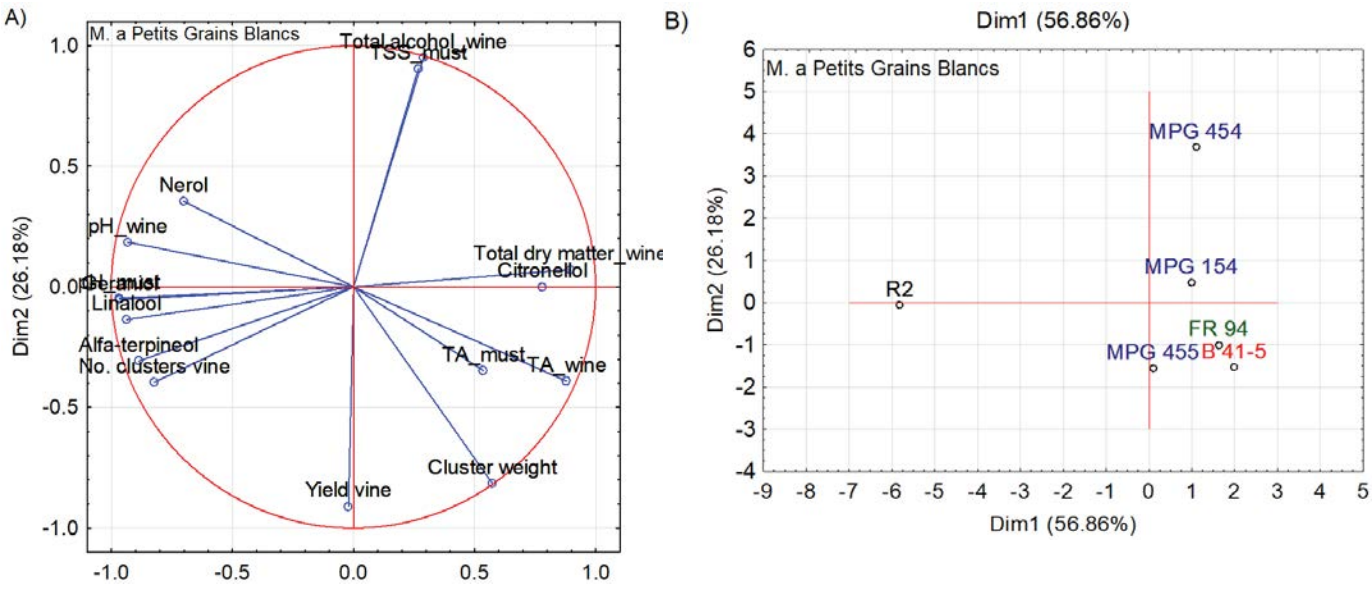

Figure 3. Principal component analyses (PCA) for the first two principal components performed on measured vine yield, must, and wine parameters of clones of M. a Petits Grains Blancs (MPG) variety in three consecutive vintages (2015, 2016, and 2017); (A) loadings, (B) score plot for the first two components. French clones are marked in blue, Austrian in red, German in green, and Italian in black

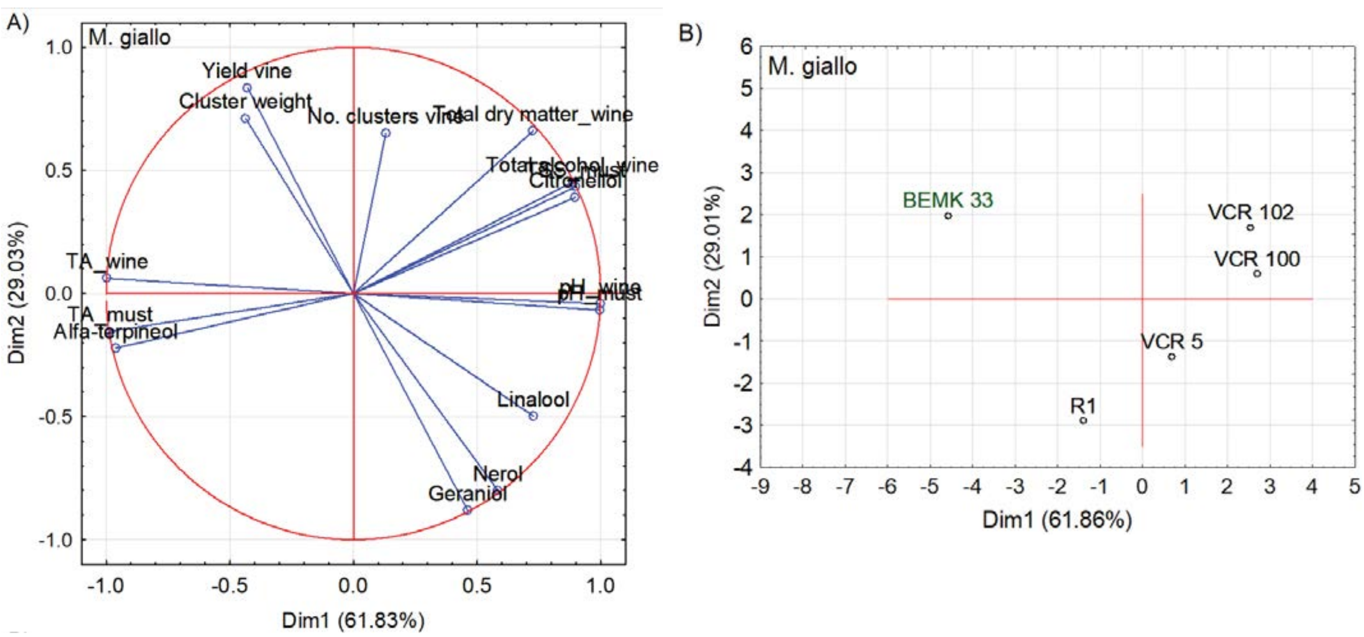

Figure 4. Principal component analyses (PCA) for the first two principal components performed on measured vine yield, must, and wine parameters of clones of M. giallo variety in three consecutive vintages (2015, 2016, and 2017); (A) loadings, (B) score plot for the first two components. The German clone is marked in green and the Italian clones in black

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