Mitteilungen Klosterneuburg 62 (2012): 143-153

Determination of manganese in musts and wines from three different wine regions of Hungary (Vintages 1992 to 2001)

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Musts and wines made from 'Cabernet Sauvignon' and 'Lemberger' grapes of the vintages 1992 to 2001 from the Hungarian wine regions Pécs, Szekszárd and Villány were analysed for their manganese content by means of AAS. Results showed that in 'Cabernet Sauvignon' weather conditions had a stronger impact on the final manganese content than in 'Lemberger'. Compared to values published in literature Hungarian red wines showed average concentrations. Mean manganese concentration of must from 'Cabernet Sauvignon' was 1.06 mg/l (n = 300), in 'Cabernet Sauvignon' wines the mean concentration was 1.35 mg/l (n = 300). Generally, 'Cabernet Sauvignon' musts from Pécs had slightly higher contents of manganese than must from Szekszárd or Villány. Mean manganese concentration of must from 'Lemberger' was 0.96 mg/l (n = 300), in 'Lemberger' wines the mean concentration was 1.24 mg/l (n = 300). 'Lemberger' musts from Villány generally showed higher manganese contents than from Pécs or Szekszárd. Daily intake of manganese regarded as being safe will not be exceeded by drinking two glasses (= 0.2 l) of 'Cabernet Sauvignon' or 'Lemberger' wine per day.
Keywords: manganese, red wine, 'Cabernet Sauvignon', 'Lemberger', atomic absorption spectroscopy

Bestimmung der Mangangehalte in Mosten und Weinen aus drei verschiedenen ungarischen Weinbauregionen. *Moste und Weine der Rebsorten 'Cabernet Sauvignon' und 'Lemberger' der Jahrgänge 1992 bis 2001 aus den ungarischen Weinbauregionen Pécs, Szekszárd und Villány wurden mittels AAS auf ihre Mangangehalte untersucht. Die Ergebnisse zeigten, dass Witterungsverhältnisse bei 'Cabernet Sauvignon' einen stärkeren Einfluss auf die Mangangehalte hatten als bei 'Lemberger'. Verglichen mit Daten aus der Literatur zeigten die ungarischen Rotweine durchschnittliche Gehalte. Die durchschnittlichen Mangangehalte von Mosten der Sorte 'Cabernet Sauvignon' waren 1,06 mg/l (n = 300), in Weinen dieser Sorte waren die durchschnittlichen Gehalte 1,35 mg/l (n = 300). Im Allgemeinen zeigten die Cabernet Sauvignon-Moste aus Pécs leicht höhere Mangangehalte als jene aus Szekszárd oder Villány. Der durchschnittliche Mangangehalt von Mosten der Sorte 'Lemberger' war 0,96 mg/l (n = 300), in Weinen dieser Sorte war der Durchschnittsgehalt 1,24 mg/l (n = 300). Lemberger-Moste aus Villány zeigten im Allgemeinen höhere Mangangehalte als jene aus Pécs oder Szekszárd. Die als unbedenklich angesehene Tagesdosis der Manganaufnahme wird mit zwei Gläsern (= 0,2 l) 'Cabernet Sauvignon' oder 'Lemberger' pro Tag nicht überschritten.*
Schlagwörter: Mangan, Rotwein, 'Cabernet Sauvignon', 'Lemberger', Atomabsorptionsspektrometrie

Détermination des teneurs en manganèse dans les moûts et les vins en provenance de trois différentes régions viticoles hongroises. *Les moûts et les vins des cépages 'Cabernet Sauvignon' et 'Lemberger' des millésimes 1992 à 2001 en provenance des régions viticoles hongroises Pécs, Szekszárd et Villány ont été examinés par SAA en vue de déterminer leurs teneurs en manganèse. Les résultats ont montré que les conditions météorologiques avaient une influence plus forte sur les teneurs en manganèse de 'Cabernet Sauvignon' que de 'Lemberger'. Par comparaison avec les données de la littérature, les vins rouges hongrois présentaient des teneurs moyennes. La teneur moyenne en manganèse des moûts du cépage 'Cabernet Sauvignon' s'élevait à 1,06 mg/l (n = 300), celle des vins de ce cépage à 1,35 mg/l (n*

= 300). En règle générale, les moûts de Cabernet Sauvignon en provenance de Pécs présentaient des teneurs en manganèse légèrement plus élevées que ceux de Szekszárd ou Villány. La teneur moyenne en manganèse des moûts du cépage 'Lemberger' était de 0,96 mg/l (n = 300), celle des vins de ce cépage s'élevait à 1,24 mg/l (n = 300). En règle générale, les moûts Lemberger de Villány présentaient des teneurs en manganèse plus élevées que ceux de Pécs ou Szekszárd. La dose journalière de manganèse considérée comme inoffensive n'est pas dépassée par la consommation de deux verres (= 0,2 l) de 'Cabernet Sauvignon' ou de 'Lemberger' par jour.
Mots clés : manganèse, vin rouge, 'Cabernet Sauvignon', 'Lemberger', spectrométrie d'absorption atomique

Determination of trace elements in food and beverages is of great interest for nutritional and toxicological purposes. Manganese plays an essential role in human metabolism, since deficiency leads to abnormalities in brain development, skeletal formation, and glucose tolerance (Keen et al., 1984). Furthermore, it is important for various enzymes involved in protein and energy metabolism. It is also important for the synthesis of mucopolysaccharides and cholesterol (NRC, 1989). Manganese deficiency as well as oversupplementation affects brain metabolism (Keen et al., 1984). To date, a general recommended daily allowance has not been published by the WHO, since reliable data on manganese toxicity is still lacking. However, daily intakes between 2.5 and 5.0 mg per day are regarded as safe (NRC, 1989). Robberecht et al. (1994) reported that daily intake of manganese in various countries is slightly over 2 mg per day: France (1.97 to 2.66 mg), Spain (2.19 to 3.02 mg), and Germany (2.0 to 3.8 mg).
Different studies have revealed that beverages can have a strong influence on daily intake of manganese (Minoia et al., 1994). Stobbaerts et al. (1995) already showed that tea and wine, and especially red wine, are important sources for manganese. According to Minoia et al. (1994) ordinary tea and wine consumption can raise the daily intake by 10 %. More recently, other authors have shown that daily consumption of 250 ml wine might lead to ingestions of manganese exceeding the so-called Target Hazard Quotients THQ (Hague et al., 2008). The same research group has published more detailed data on wine (Naughton and Petroczi, 2008). Yet, the observed manganese levels did not exceed 5.5 µg/l wine. This is in strong discrepancy to the former published values and might be due to a miscalculation. But even if concentrations should be a 1,000-fold, i.e. 5 mg/l, a daily glass of wine would not lead to an oversupply of manganese in consideration of the data published by the National Research Council (NRC, 1989).
Moreover, and more from an oenological point of view, manganese has also a strong influence on the tendency of wines to oxidise more rapidly (Fernandez, 1988). Cacho et al. (1995) used Spanish model wines to analyse the impact of increasing manganese concentrations on tannins and anthocyanins. Their results showed that higher manganese concentrations ultimately lead to stronger oxidative losses in anthocyanins and tannins during storage.

Generally, data on manganese content of Hungarian wines is scarce. Various studies are available on French (Etievant et al., 1988; Cabrera-Vique et al., 2000), Italian (Minoia et al., 1994), Cretian (Galani-Nikolakaki et al., 2002), and Spanish (Stobbaerts et al., 1995; Frías et al., 2003) red wines. One study on Hungarian wines has been published by Szentmihályi et al. (2000). They found manganese concentrations between 0.074 and 0.368 mg/l in red wines from different wine regions of Hungary.
The aim of this study was to provide more data on general manganese content of Hungarian red wine. We also wanted to analyse the influence of different regions, varieties, and vintage years on the final manganese content.

Materials and Methods

Instrument (AAS)

An atomic absorption spectrometer (Perkin Elmer 3110, Norwalk CT, USA) was used. Samples were analysed at 279.8 nm with a slit width of 0.7 mm. A hollow cathode lamp ("Intensitron" Perkin Elmer, 25mA,) was used. Samples were injected by means of an autosampler (Perkin Elmer, AS 90). An acetylen (flow: 7 ml/min) and air (flow: 24 ml/min) flame was used for atomisation. All samples were analysed in tri-

plicate. Every day an external standardisation was performed. The resulting calibration curve was used to calculate manganese concentration of the samples.

Samples

All grapes were harvested each year at the same locations: Pécs, Szekszárd und Villány. We chose two varieties: 'Cabernet Sauvignon' (*Vitis vinifera* convar. *occidentalis*) and 'Lemberger' (*Vitis vinifera* convar. *orientalis*). The grapes were all processed by the same vinification procedure. Grapes were handpicked at commercial ripeness. They were then crushed and destemmed by means of a Cantinetta C.D.A. TR (Nuova Zambelli, Saonara, Italy) destemmer/crusher. After crushing the mash received 20 mg/l SO_2. They were then inoculated with selected dry yeast (EC 1118, Fa. Lallemand) and fermented till dryness at 14 °C. The wines were then racked off the lees and received 50 mg/l SO_2. From each location ten musts and wines, respectively, were made every year. For vinification only 20 l plastic/glass vessels and hoses were used to avoid manganese contamination through the use of stainless steel or alloy made containers.

Sample preparation method

10 ml of sample were desiccated to dryness and dissolved in a mixture of 8 ml 65 % HNO_3, 1 ml 70 % $HClO_4$ and 1 ml 97 % H_2SO_4 for 2 h. Afterwards nitric acid was fumed off and samples mineralised in a furnace. After cooling 10 ml of bi-distilled water were added and heated to boiling point. After 3 h samples were made up to volume with acidified water (0.5 ml conc. sulphuric acid in 1 l water) in a 25 ml volumetric flask and analysed by means of AAS after filtration over ash free filter paper (640md, Macherey-Nagel, Düren, Germany).

Calibration

Calibration was performed before each measurement using external calibration method at 0.5; 1.0; 2.5; 5.0; 7.5; 10.0 ppm.). The respective calibration curve (in all cases R^2 = 1.000) was used for calculation of manganese content of the samples.

Statistics

For statistic analysis of the results the following software was used: Excel® (Office 2000, Microsoft Corp./USA) and SPSS for Windows® (Version 10.0, SPSS Corp./USA).

Results and Discussion

'Cabernet Sauvignon'

Musts

Compared to the 10-year mean of the musts shown in Table 1 the musts of the vintage 1995 showed very low manganese concentrations from all regions analysed. The year 1995 had been very warm (mean temperature: 25.2 °C; 10-year mean: 22.7 °C), sunny (297 h sunshine; 10-year mean: 274 h), and exceptionally dry (11 mm rainfall; 10-year mean: 92 mm) in July. July is a very important stage during the vegetation periods of grapevines. Especially during the third and forth vegetation period (i.e., July/August) grapes showed higher contents on manganese calculated on dry-weight (Kozma, 2000). Under exceptionally dry weather conditions, such as during July 1995, sufficient uptake of this mineral from the soil is thus hindered. This has direct consequences for photosynthesis and also development of the grapes. Both processes are slowed down, if not completely stopped. Magnesium, which follows similar uptake pathways from the soil as manganese, also showed much lower contents in the musts from 1995 (data not shown).
Canonical discriminant analysis revealed that beside 1995 the year 1992 also showed a distinctly different composition compared to the other vintages (Fig. 1). In 1992 the manganese contents were very high (overall mean 1.75 mg/l). This result was supported by ANOVA, which showed that both vintages show significant differences with regard to their manganese content. This could be due to the higher rainfall in June 1992, which was 48 mm higher than the 50-year mean in Pécs.
Of the regions surveyed musts from Pécs showed highest contents in manganese (Pécs 1.17 mg/l; Szekszárd 0.97 mg/l; Villány 1.03 mg/l, 10-year mean). In Pécs the soil is mainly brown duff on sandstone, while in Szekszárd and Villány the soil is brown duff on loess. Due to the much lower contents of sandstone soils on manganese one would expect lower concentrations in the samples from Pécs (Scheffer and Schachtschabel, 2002). Yet, nearly similar values were found in all

three regions. Thus, seasonal differences are most probably of greater influence than the different bedrocks. According to canonical discriminant analysis the three different regions could probably be separated on the basis of their manganese content (Fig. 2). This would support our supposition that different sites might have a strong impact on the final manganese content. Yet, ANOVA showed that the regional differences within the same vintage year are relatively small albeit a statistical difference could be observed in some cases. Obviously, seasonal differences are of much greater influence than different soil material as already mentioned above.

Wine

The resulting wines showed fewer variations in manganese content from year to year compared to their respective musts. Especially in Villány the manganese content was always around 1.3 mg/l (Table 3). Compared to that, the wines from Szekszárd showed higher variations, but they did not go hand in hand with those observed in the respective musts. In Szekszárd the concentrations in the musts had actually been rather constant and only the wines of vintage 1995 showed abnormalities which is probably due to the extremely dry weather conditions in this year as already discussed above. Yet, this trend was not observed in the respective wines. Furthermore, in 1993 and 2000 manganese content of the wines from Szekszárd had been very low. This could also be due to climatic conditions, since manganese content in the respective musts has been relatively low albeit not as low as in 1995 (Table 1). Summer in these years has been much drier compared to the 50-year mean. Rainfall in June, July, and August was 110 mm less than average. These low contents in manganese are, thus, most probably a result of a combination of climatic conditions and certain enological influences (reduction of manganese through lees sedimentation etc.).
Canonical discriminant analysis did not reveal a clear influence of vintage on the concentration of manganese in the respective wines (Fig. 3). Only the 2000 vintage seemed to be of certain difference. In Szekszárd and Villány the vintage 1992 showed the highest manganese contents, while the 2000 vintage showed the lowest, which could be due to the dry weather conditions as already discussed above. In Pécs, on the contrary, both vintages showed mean concentrations of manganese. This was also supported by ANOVA (Table 2).
Canonical discriminant analysis revealed that the wines can probably be separated according to region (Fig. 4). An ANOVA conducted on all data showed that in several years manganese content was significantly ($p < 0.05$) higher in wines from Pécs (Table 2). Szekszárd and Villány could not be separated on the basis of their manganese content (Fig. 4). Based on the fact that the respective musts showed similar tendencies the "human/yeast factor", i.e. enological treatments, did not alter the manganese content in a way that different ratios occurred in the finished wines.

'Lemberger'

Must

In musts of the variety 'Lemberger' the vintage year does not seem to have such a strong influence on manganese content like in 'Cabernet Sauvignon'. Variations are much smaller, especially in the year 1995 when 'Cabernet Sauvignon' had been largely affected by weather conditions. 'Lemberger' did not show large differences between the regions (Table 3). Only in the year 1994 some variations compared to the other vintages could be observed (Fig. 5). In Villány, this vintage showed a significantly higher manganese content than all other vintages. Furthermore, in Szekszárd the content was also the highest albeit not statistically significant. In Pécs rather low concentrations were found in the respective vintage (Fig. 6). Weather conditions in this year showed 91 mm more rainfall during the summer period (June to August) compared to the 50-year average. Thus, assimilation of manganese was probably easier through wetter soil conditions.
The smaller variations in manganese content in the variety 'Lemberger' despite changing weather conditions suggest that this variety seems to be more capable of mobilising mineral reserves under stress. From different research trials at the Research Institute in Pécs (Hungary) we can confirm that 'Lemberger' is less sensitive to drought and stress than 'Cabernet Sauvignon', especially with regard to water potential and photosynthesis rate (Teszlák, pers. communication). Since ten different rootstocks (T 5C, T 5C Gm6, T 5C Gm1, T 5C WED, TK 5BB, TK 5BB F, TK 5BB W, TK 5BB C, TK 125AA, T4A SO4) were tested within this trial and no significant differences between the used rootstocks were found, we can assume that these rootstocks do not have a significant impact on the final manganese content of either variety (data not

shown). Also ANOVA revealed statistically differences based on origin of the musts albeit these differences were much smaller than in 'Cabernet Sauvignon'. This can also be observed in the canonical discriminant analysis, which reflects the small differences between vintage years and origin (Fig. 5 and 6).

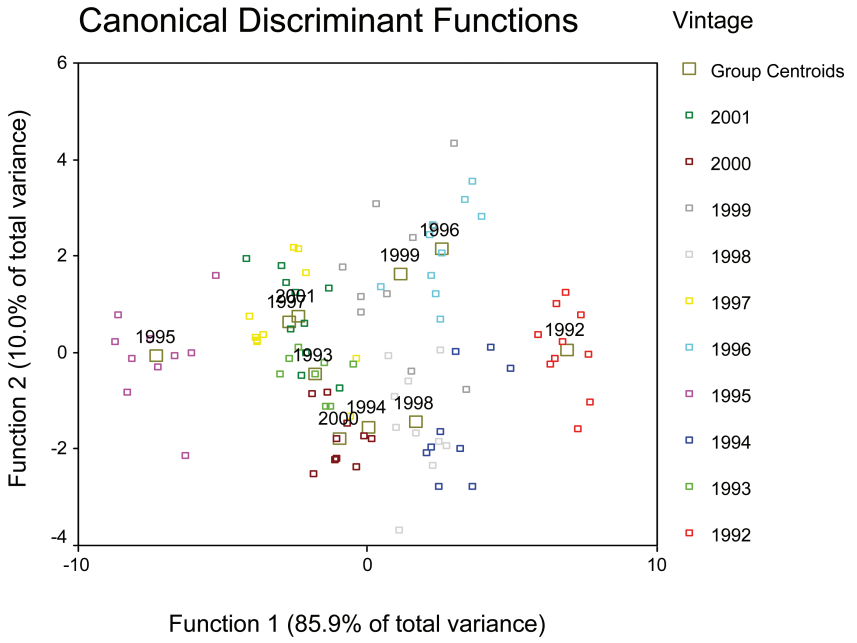

Fig. 1: Canonical Discriminant Analysis of 'Cabernet Sauvignon' must for manganese content (mg/l) according to vintage year (vintages: 1992 to 2001; n = 300)

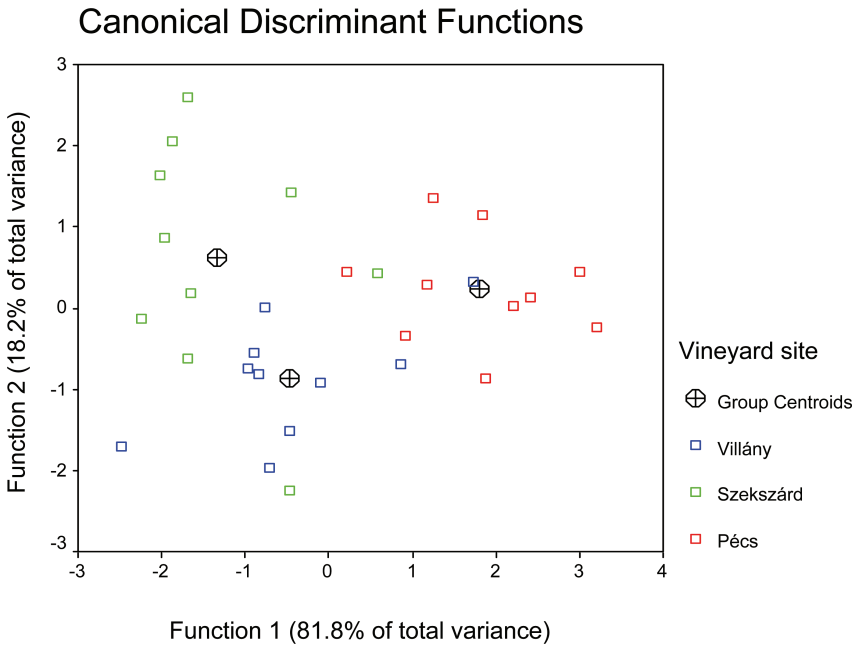

Fig. 2: Canonical Discriminant Analysis of 'Cabernet Sauvignon' must for manganese content (mg/l) according to vineyard site (vintages: 1992 to 2001; n = 300)

Table 1: Manganese content (mg/l) of 'Cabernet Sauvignon' musts from Pécs, Szekszárd, and Villány of the vintages 1992 to 2001; rows with different letters are statistically significant ($p < 0.05$)

Year	N	Pécs	Szekszárd	Villány
1992	10	1.96 ± 0.107 a	1.68 ± 0.218 b	1.62 ± 0.274 b
1993	10	0.80 ± 0.082 a	1.00 ± 0.223 b	0.90 ± 0.279 ab
1994	10	1.40 ± 0.245 a	1.00 ± 0.228 b	1.44 ± 0.285 a
1995	10	0.28 ± 0.193 a	0.34 ± 0.233 a	0.40 ± 0.290 a
1996	10	1.81 ± 0.255 a	1.20 ± 0.238 b	1.06 ± 0.295 b
1997	10	0.83 ± 0.170 ab	0.99 ± 0.244 a	0.72 ± 0.300 b
1998	10	1.17 ± 0.212 ab	1.06 ± 0.249 a	1.30 ± 0.305 b
1999	10	1.62 ± 0.347 a	0.93 ± 0.254 b	0.99 ± 0.310 b
2000	10	0.84 ± 0.108 a	0.75 ± 0.259 a	1.11 ± 0.315 b
2001	10	1.01 ± 0.127 a	0.75 ± 0.264 b	0.75 ± 0.321 b
Total	100	1.171 ± 0.213	0.97 ± 0.269	1.03 ± 0.326

Table 2: Manganese content (mg/l) of 'Cabernet Sauvignon' wines from Pécs, Szekszárd, and Villány of the vintages 1992 to 2001; rows with different letters are statistically significant ($p < 0.05$)

Year	N	Pécs	Szekszárd	Villány
1992	10	1.64 ± 0.128 a	1.51 ± 0.130 ab	1.38 ± 0.087 b
1993	10	1.74 ± 0.180 a	0.92 ± 0.178 c	1.37 ± 0.119 b
1994	10	1.41 ± 0.235 a	1.08 ± 0.135 b	1.31 ± 0.048 a
1995	10	1.31 ± 0.146 a	1.26 ± 0.217 a	1.36 ± 0.099 a
1996	10	1.98 ± 0.420 a	1.12 ± 0.070 b	1.33 ± 0.099 b
1997	10	1.24 ± 0.071 a	1.24 ± 0.125 a	1.15 ± 0.096 a
1998	10	1.60 ± 0.163 a	1.11 ± 0.190 b	1.21 ± 0.140 b
1999	10	1.71 ± 0.105 a	1.42 ± 0.194 b	1.33 ± 0.170 b
2000	10	1.61 ± 0.227 a	0.83 ± 0.118 c	1.12 ± 0.142 b
2001	10	1.57 ± 0.168 a	1.37 ± 0.171 b	1.26 ± 0.124 b
Total	100	1.58 ± 0.292	1.19 ± 0.259	1.28 ± 0.149

Table 3: Manganese content (mg/l) of 'Lemberger' musts from Pécs, Szekszárd, and Villány of the vintages 1992 to 2001; rows with different letters are statistically significant ($p < 0.05$)

Year	N	Pécs	Szekszárd	Villány
1992	10	1.43 ± 0.397 a	1.13 ± 0.258 a	1.18 ± 0.092 a
1993	10	0.83 ± 0.082 a	0.80 ± 0.082 a	0.76 ± 0.070 a
1994	10	0.78 ± 0.092 a	1.24 ± 0.324 ab	1.62 ± 0.688 b
1995	10	0.72 ± 0.078 ab	0.59 ± 0.120 b	0.73 ± 0.151 a
1996	10	1.22 ± 0.192 a	0.79 ± 0.121 b	1.07 ± 0.105 a
1997	10	0.80 ± 0.138 a	0.81 ± 0.087 a	0.82 ± 0.062 a
1998	10	1.35 ± 0.230 a	1.12 ± 0.189 b	1.13 ± 0.078 b
1999	10	1.11 ± 0.154 a	1.21 ± 0.270 a	1.14 ± 0.130 a
2000	10	0.69 ± 0.075 a	0.68 ± 0.112 a	0.99 ± 0.029 b
2001	10	0.72 ± 0.130 a	0.51 ± 0.059 b	0.77 ± 0.166 a
Total	100	0.96 ± 0.322	0.89 ± 0.309	1.02 ± 0.346

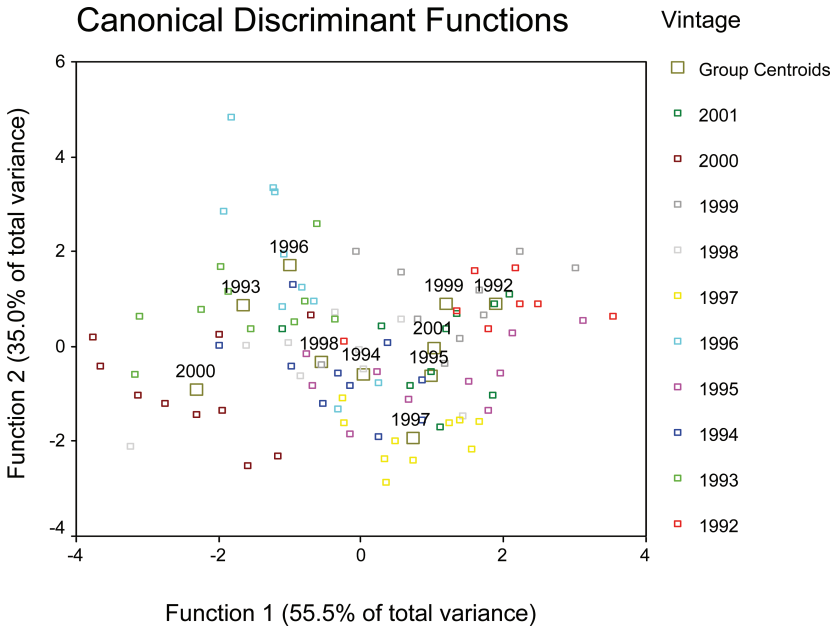

Fig. 3: Canonical Discriminant Analysis of 'Cabernet Sauvignon' wine for manganese content (mg/l) according to vintage year (vintages: 1992 to 2001; n = 300)

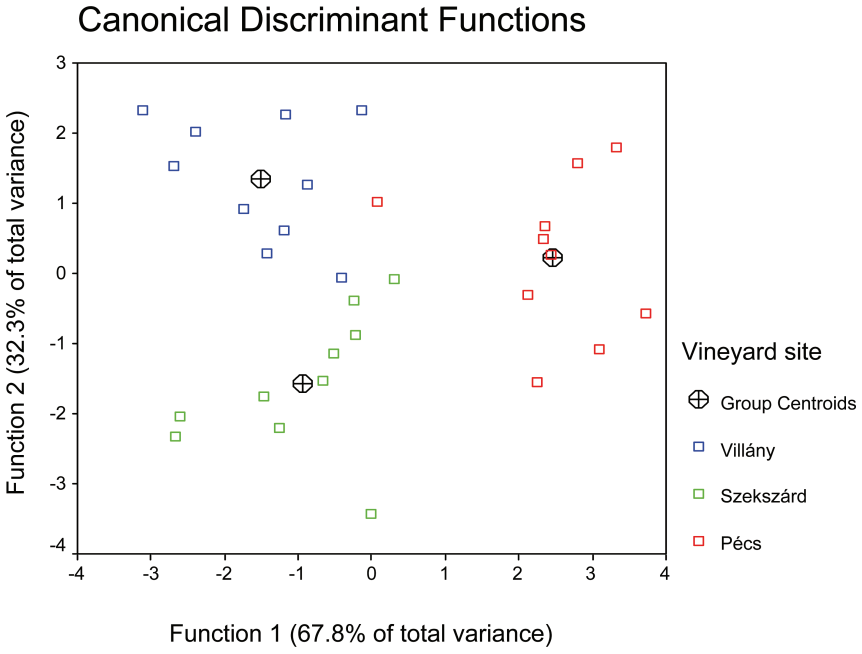

Fig. 4:Canonical Discriminant Analysis of 'Cabernet Sauvignon' wine for manganese content (mg/l) according to vineyard site (vintages: 1992 to 2001; n = 300)

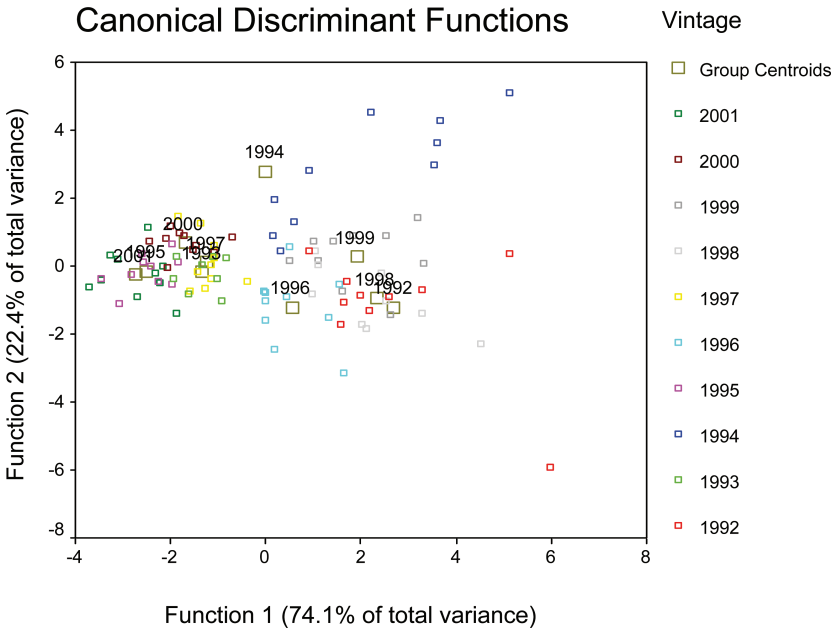

Fig. 5: Canonical Discriminant Analysis of 'Lemberger' must for manganese content (mg/l) according to vintage year (vintages: 1992 to 2001; n = 300)

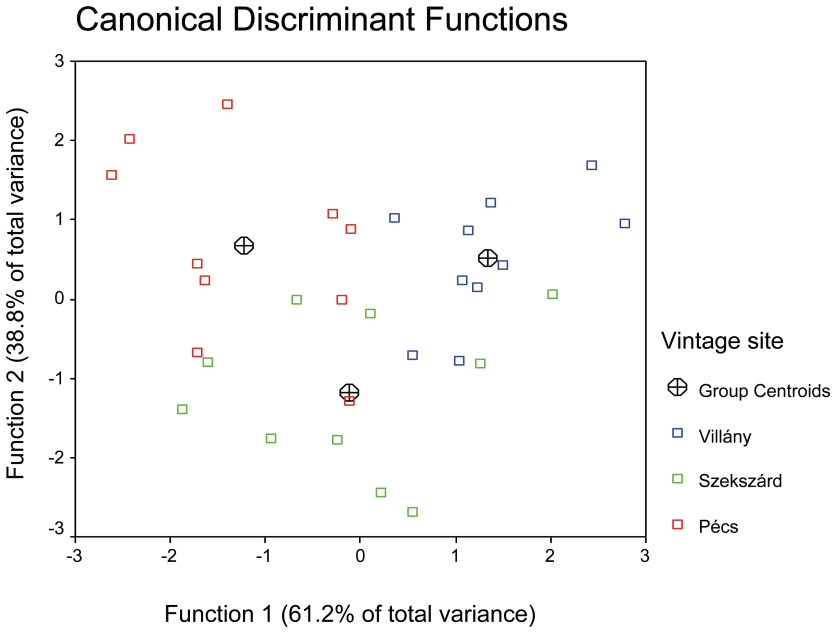

Fig. 6: Canonical Discriminant Analysis of 'Lemberger' must for manganese content (mg/l) according to vineyard site (vintages: 1992 to 2001; n = 300)

Wine

The results of the analysis and ANOVA are given in Table 4. According to ANOVA regional differences seemed to have a weak impact on the final manganese content. Yet, seasonal influences over-imposed the impact of soil on the manganese content. Canonical discriminant analysis revealed that the vintage 1992 was completely different compared to the other vintages (Fig. 7). The higher rainfall in June and July (56 mm more than the 50-year average) might have led to this stronger assimilation of manganese in the vines.
During 1992 and 1994 the wines from Pécs, Villány, and – partially – Szekszárd showed higher manganese contents than in the following years. This could be due to the higher rainfalls in the autumn and winter of these years. In the year 1992 162 mm and in the year 1993 263 mm more rainfall were measured from September to December compared to the 50 year average. The high humidity in the soil might have mobilized the manganese in the soils and, thus, it was readily available during the vegetative stage.
During the following years manganese concentrations came back to the same level, which had also been observed in the wines of variety 'Cabernet Sauvignon' (around 1.2 mg/l), but showed less variations than in 'Cabernet Sauvignon'. This could be due to the already mentioned higher resistance of 'Lemberger' against water stress. The wines from Szekszárd generally showed the lowest contents on manganese (Fig. 8). This trend was already observed in the musts and in the analysed musts and wines of 'Cabernet Sauvignon'. Thus, it can be assumed that this region has generally lower contents of manganese in the soil.

Comparison with literature data

Hungarian red wines had manganese concentrations comparable to those published in literature. Cabrera-Vique et al. (2000) found between 0.44 and 7.84 mg/l in French red wines. Etievant et al. (1988) found concentrations between 0.4 and 0.85 mg/l in French wines, while values of Spanish wines published by Cabrera et al. (1995) were around 0.56 ± 0.39 mg/l. Stobbaerts et al. (1995) analysed 35 wines from different varieties and origins. Their results were around 2.7 ± 1.7 mg/l, and they could not detect a statistically significant difference between red and white wine. Compared to values published by Szentmihályi et al. (2000) in this paper distinctly higher concentrations are reported.

In summary, seasonal tendencies have been observed for either variety in musts and wines. Also regional differences were found but seem to be overruled by seasonal differences. Furthermore, vinification might have a strong influence on the final manganese concentration due to the clarifying effect of lees sedimentation or bentonite fining. Yet, the latter was not performed during the scope of this study, since bentonite fining is known to increase the manganese content of wines significantly (Nicolini et al., 2004).

Conclusions

Important factors having a strong impact on the final manganese content of grapes and wines are location, soil composition, and weather conditions. Very dry weather obviously leads to insufficient uptake of this mineral from the soil, which hitherto can contribute to reductions in photosynthesis rate and retardation of ripening in 'Cabernet Sauvignon'. 'Lemberger' seems to be more resistant to stress (drought) and/or seems to be more capable of mobilising mineral reserves under these conditions and, thus, manganese concentrations in the respective musts and wines were not found to vary as much as in 'Cabernet Sauvignon'. Vinification procedures, such as bentonite fining, are described to have a strong impact on the final manganese content of the wine. Therefore, for comparative reasons only results from must analysis should be considered.
According to our results two glasses of red wine (= 0.2 l) would already contribute to the daily intake in manganese by 10 %, thus affirming the values published by Minoia et al. (1994). Therefore, we can conclude that red wine of the 'Cabernet Sauvignon' and 'Lemberger' variety from the Hungarian Pécs, Szekszárd, and Villány regions is a good source of this essential mineral. In opposition to the data recently published by Naughton and Petroczi (2008) and Hague et al. (2008) according to our results daily manganese intake regarded as being safe will not be exceeded by moderate consumption of these wines.

Acknowledgements

The authors would like to thank Dr. Péter Teszlák (Pécs) for providing weather data and Dr. Dietmar Rupp (Weinsberg) for helpful discussions.

Table 4: Manganese content (mg/l) of 'Lemberger' wines from Pécs, Szekszárd, and Villány of the vintages 1992 to 2001; rows with different letters are statistically significant ($p < 0.05$)

Year	N	Pécs	Szekszárd	Villány
1992	10	1.68 ± 0.160 a	1.64 ± 0.162 a	1.45 ± 0.112 b
1993	10	1.74 ± 0.180 a	0.92 ± 0.178 c	1.37 ± 0.119 b
1994	10	1.66 ± 0.129 b	1.30 ± 0.143 c	2.00 ± 0.212 a
1995	10	1.21 ± 0.106 b	1.02 ± 0.095 c	1.34 ± 0.074 a
1996	10	1.19 ± 0.104 a	1.04 ± 0.170 b	1.01 ± 0.270 b
1997	10	0.95 ± 0.119 ab	0.87 ± 0.117 b	1.12 ± 0.155 a
1998	10	1.30 ± 0.133 a	0.88 ± 0.069 c	1.08 ± 0.111 b
1999	10	1.31 ± 0.110 a	1.13 ± 0.370 a	1.34 ± 0.123 a
2000	10	1.24 ± 0.098 a	0.88 ± 0.098 b	1.26 ± 0.092 a
2001	10	1.19 ± 0.109 a	0.88 ± 0.085 b	1.08± 0.100 a
Total	100	1.35 ± 0.290	1.05 ± 0.268	1.30 ± 0.320

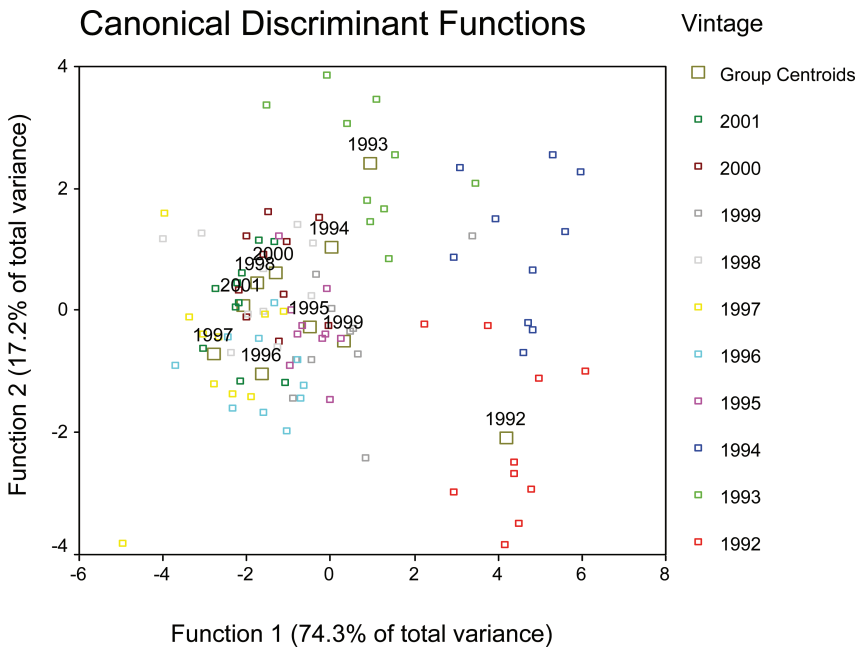

Fig. 7: Canonical Discriminant Analysis of 'Lemberger' wine for manganese content (mg/l) according to vintage year (vintages: 1992 to 2001; n = 300)

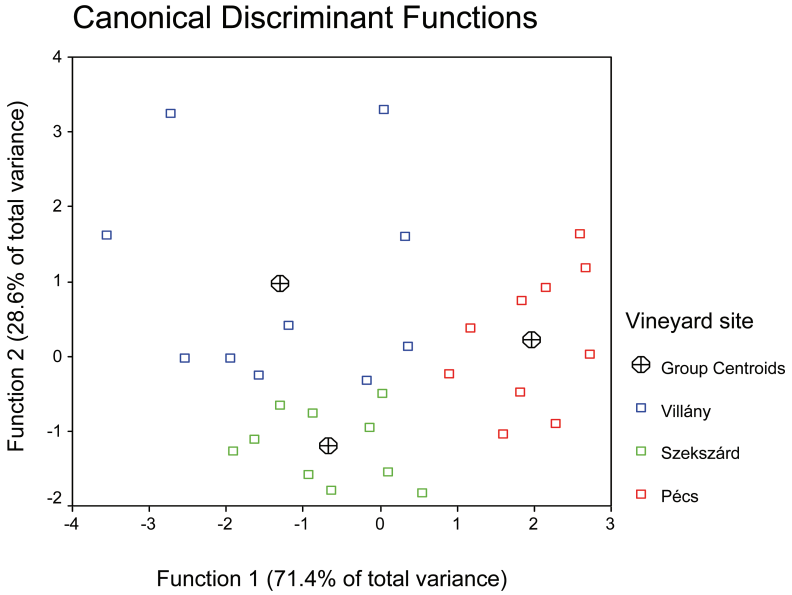

Fig. 8: Canonical Discriminant Analysis of 'Lemberger' wine for manganese content (mg/l) according to vineyard site (vintages: 1992 to 2001; n = 300)

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Received October 21, 2010