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Investigations into the correlation between boron concentration and yield characteristics with the grape cultivar 'Cabernet Sauvignon' on different rootstocks

Anna Csikász-Krizsics and Lajos Diófási

Research Institute for Viticulture and Oenology, Pécs
H-7634 Pécs, Pázmány P. u. 4
E-mail: krizsics.anna@szbki-pecs.hu

Although grapevine is highly sensitive to boron content in the soil, it has a moderate need for boron. The uptake of boron from the soil is inhibited by pH-values below 5 and above 7, respectively. Boron deficiency mainly occurs on poor, sandy, dry and calciferous soils. The appropriate choice of rootstocks varieties makes it possible to influence the boron content of the vine. Within a twelve-years experiment (1992 to 2003) the correlations between boron content of the leaves and in the must, and the quantitative, qualitative parameters of the yield, respectively, were investigated in a vineyard with limited boron uptake. 'Cabernet Sauvignon' was tested on the following nine rootstocks: '5C' (clones: Gm.6, Gm.10, Wed.); '5BB', (clones: Fr.148, Wei.48, Cr.2) '125AA' and 'SO4'. The rootstock '5BB' clone Cr.2 showed the highest boron content in the leaves at bloom and ripening and also in must while the rootstock '5C' clone Wed. showed the lowest values among the examined rootstocks. By regression analysis we found a positive correlation between the boron content and the must-weight as well as the pH-value. The correlation between the boron content of the must and the amount of yield was negative. The boron concentrations of the leaves were connected to the concentration of nitrogen, and also correlated to the titratable acid content of the musts.
Keywords: 'Cabernet Sauvignon', rootstocks, leaf analysis, must analysis, boron

Untersuchungen über die Zusammenhänge von Borkonzentration und Ernteparametern bei der Sorte 'Cabernet Sauvignon' auf verschiedenen Unterlagen. *Die Weinrebe ist zwar in Bezug auf den Borgehalt sehr empfindlich, zeigt aber doch einen gemäßigten Bedarf an Bor. Die Boraufnahme aus dem Boden wird durch pH-Werte unter 5 bzw. über 7 gehemmt. Bormangel tritt in erster Linie auf kargen, sandigen, kalkhaltigen und trockenen Böden auf. Die entsprechende Unterlagenwahl ist eine Möglichkeit zur Optimierung der Borkonzentration. Mittels einer zwölf Jahre dauernden Untersuchung (1992 bis 2003) wurden die Zusammenhänge zwischen dem Borgehalt der Blätter und des Mostes bzw. der quantitativen und qualitativen Ernteparameter in einem Weingarten mit Bormangel untersucht. 'Cabernet Sauvignon' wurde auf den folgenden neun Unterlagen getestet: '5C', (Klone: Gm.6, Gm.10, Wed.) '5BB', (Klone: Fr.148, Wei.48, Cr.2) '125AA' und 'SO4'. Die Unterlage '5BB' clone Cr.2 zeigte die höchsten Borgehalte in den Blättern zur Blüte und zur Reife und im Most, während die Unterlage '5C' clon Wed. die geringsten Werte der untersuchten Unterlagen zeigte. Mittels Regressionsanalyse wurde eine positive Korrelation zwischen Borgehalt und Mostgewicht und pH-Wert festgestellt. Die Borgehalte der Moste und die Erträge korrelierten negativ. Die Borgehalte der Blätter zeigten einen Zusammenhang mit der Stickstoffkonzentration und korrelierten auch mit dem Gehalt an titrierbarer Säure im Most.*
Schlagwörter: 'Cabernet Sauvignon', Unterlage, Blattanalyse, Mostanalyse, Bor

Recherches relatives aux rapports entre la concentration en bore et les paramètres de vendange du cépage 'Cabernet Sauvignon' sur différents porte-greffes. *Il est vrai que la vigne est très sensible à la teneur en bore mais, en re-*

vanche, qu'elle présente un besoin modéré en bore. L'absorption du bore du sol est inhibée par des pH inférieurs à 5 ou supérieurs à 7. Un manque de bore existe en premier lieu sur les sols pauvres, sableux, calcaires et secs. La sélection du porte-greffe correspondant est une possibilité d'optimiser la concentration en bore. Les rapports entre la teneur en bore des feuilles et du moût et les paramètres de vendange quantitatifs et qualitatifs ont fait l'objet d'un essai durant douze ans (de 1992 à 2003) effectué dans un vignoble présentant un manque de bore. 'Cabernet Sauvignon' a été testé sur les neuf porte-greffes suivants : '5C', (clones : Gm.6, Gm.10, Wed.) '5BB', (clones : Fr.148, Wei.48, Cr.2) '125AA' et 'SO4'. Le porte-greffe '5BB' clone Cr.2 présentait les teneurs en bore des feuilles les plus élevées lors de la floraison et de la maturité, tandis que le porte-greffe '5C' clone Wed. présentait les valeurs les plus basses de tous les porte-greffes examinés. Une corrélation positive entre la teneur en bore, la densité du moût et le pH a été établie au moyen de l'analyse de régression. Les teneurs des moûts en bore et les rendements présentait une corrélation négative. Les teneurs en bore des feuilles étaient en rapport avec la concentration en azote et corrélaient également avec la teneur en acide titrable dans le moût.
Mots clés : 'Cabernet Sauvignon', porte-greffe, analyse des feuilles, analyse du moût, bore

The importance of boron for higher plants was demonstrated already by AGULHON (1910). Boron is essential for cell wall structure as well as membrane function. Boron is also a vital element in development and growth of new cells, carbohydrate metabolism and translocation of starch and sugars. It is indispensable in nitrogen and phosphorus metabolism, in synthesis of amino-acids and proteins. It has a role in RNA and DNA synthesis, embryonary development, and hormonal regulation (BERGMANN, 1979; KELLER, 2005). PARR and LOUGHMAN (1983) found out, that boron increased membrane permeability for chlorine and phosphorus. The micronutrient boron is essential to keep the ATP pump going, so that a boron deficit strongly reduces the nitrate uptake the roots (CAMACHO-CRISTÓBAL and GONZÁLEZ-FONTES, 1999). Other studies have shown that supplemental boron stimulates proton pumping in plants, causes hyperpolarization of the membrane potential, and increases potassium uptake (BLEVINS and LUKASZEWSKI, 1994). Deficiency symptoms firstly appear at shoot tips, at root tips or secondly at pollen tube tips and are characterized by cell wall abnormalities (LOOMIS and DURST, 1992).

Boron can be classified as having variable or conditional phloem mobility (WELCH, 1986). This mobility depends on plant species, environmental influences, plant tissue and growing stage (WELCH and RENGEL, 1999). In species, in which sorbitol is a major sugar, boron is freely mobile, whereas in species that produce little or no sorbitol boron is largely immobile (BROWN and HU, 1996). Boron uptake is most intensive at the beginning of the vegetation period and continually increasing till veraison (FREGONI, 1984). Demand of boron is significant at the time of the flower development, adosculation and during the cell division of fruit. Dry and drought weather also makes the uptake of boron more difficult (PEACOCK and CHRISTENSEN, 2005). According to SCOTT and SCHRADER (1947) there was a definite transfer of boron from the lower mature leaves of the vine upward to the terminal, actively growing parts. Thus the amount transferred was sufficient to maintain normal growth of the vine for a limited period of time, or until the lower leaves were depleted of boron to a certain level. Boron accumulated in the berry during all stages of development, rates of accumulation, however, were highest after veraison. The concentrations of potassium, boron and copper continued to increase throughout berry development (ROGIERS et al., 2006).

Boron is a unique microelement because the interval between deficiency and toxic level is rather small. So, at a given location the appropriate choice of rootstock makes it possible to optimise the concentration of boron. DELAS and POUGET (1979) found that on one hand, the rootstock modifies the element content of the vine and also modifies the sensitivity to the deficit of the particular element, and on the other hand, the composition of the leaves depended on both the rootstock and the scion. According to the investigations of AVENANT et al. (1997) the rootstock had a significant effect on the quality of the grapes and the wine as well.

Materials and Methods

Conditions

A field experiment was set up at Szentmiklós hill (near Pécs, northern latitude: 46,07°, eastern longitude: 18,17°) in southern Hungary. The experimental plot was on the southern slope of West-Mecsek hill, two hundred metres above sea-level. 50 years' average weather conditions of the site during the vegetation period are an average temperature of 17.5 °C and 510 mm of

precipitation per year. The most important weather parameters (temperature, amount of precipitation and the number of sunshine hours) during the experimental period (1992 to 2003) are shown in Table 1.
The soil of the site is a slight layer of Permian sandstone detritus. It is a medium adherent, a little bit calciferous, sandy-loam soil with medium humus content. A complete analysis of samples of the soil was made in 1990, the results are given in Table 2. In Table 3 the soil analysis of 2001 can be found.

Rootstocks

The 'Cabernet Sauvignon' (*Vitis vinifera L.*) plantation was established in 1986. Row distance and spacing are 3.5 x 1.2 meters, the training system was an "umbrella" with cane pruning.
This study organized in a randomised block design, consisting of four replicates and four vines per replicate. The experiment was carried out with the following rootstocks: '5C' and the clones Gm6, Gm10 and Wed.; '5BB' and the clones Fr.148, Wei.48 and Cr.2, '125AA' and 'SO4'. It is well accepted that a rootstock can affect foliar nutrient levels, but the complex interactions of rootstock, rootstock-scion combination, soil type, climate and management practice have made it challenging to acquire sufficient and consistent information on rootstock mineral nutrition (Wolpert et al., 2005). In our opinion, in this context the examination of rootstock clones also is of importance. Kocsis and Podmaniczky (2005) also stated that rootstock adaptability to a given soil type is a key factor for assuring quality.

Leaf-analysis

Since 1990 we have examined the boron supply of the 'Cabernet Sauvignon' (E.153 clone) cultivar (and also eight other nutrients were determined) with the help of plant analysis of leaf blade samples collected at bloom and ripening, located opposite the cluster. The leaf blade samples (30 to 40 leaves per sample) were washed in distilled water, dried and ground. The concentrations of elements were determined according to standard methods, where nitrogen was determined according to Kjeldahl. Phosphorus and boron contents of the leaves were measured by spectrophotometer using standard row. The determination of the elements K, Ca, Mg, Zn, Fe, Mn was carried out by means of atomic absorption spectrometry. Concentrations were expressed as a percentage of total dry weight. Between 1992 and 2003 we also determined the boron content of the must.

Measured yield parameters

The following parameters were also measured: cluster- and pruning weight (average of 4 plants, kg), the must weight (°Brix), the titratable acid content (g/l as tartaric acid) and the pH-value of the processed fruit. Cluster crops were measured by repetition and calculated per plant. After processing harvested grapes, the quality parameters of each must sample were immediately determined.

Statistics

The effect of the rootstocks was evaluated by a two-way analysis of variance (ANOVA without repetitions), while the correlations were examined by regression analysis.

Results and Discussion

Rootstock effect on the boron content of the leaves

In the average of the examined years, the boron content of the leaves at the time of bloom was in the optimum range and at ripening it was at the lower limit of that range. Nevertheless, in half of the examined years (1992 to 1994, 1996 to 1997, 2000) a boron deficiency was detected at the time of ripening (Table 7). Boron contents of the leaves, like that of nitrogen, phosphorus and potassium, gradually decreased during growing season from April to end of October (Füleky, 1999).
Estimating the results by a two-way analysis of variance we found a significant difference regarding the boron uptake of the individual rootstocks over 12 years.
During an experiment that lasted more than ten years Csikászné and Diófási (2006) observed that 'Cabernet Sauvignon' at three different sites of production showed the highest boron content on 'SO4' rootstock.
With 'Cabernet Sauvignon' on rootstock '420A', '101-14' and '41B' Tardáguila et al. (1995) did not find any effect of the rootstock variety on boron contents or any significant interaction between the examined parts of the plant. In their opinion the growth modification induced by the rootstocks probably influences the accumulation and distribution of mineral elements. Some rootstocks seem to have an effect on the concentration of the vegetative parts mainly, while others affect the reproductive parts. This behaviour can depend on the vigour induced by the rootstock.
We measured a significantly lower boron concentration

Table 1: Meteorological data of Pécs

Temperature (°C)

Month	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	Average period	Average 50 years
January	2.3	2.5	3.4	0.3	-1.5	-1.7	3.5	0.9	-0.8	2.2	1.4	-0.6	1.0	0.2
February	4.5	0.4	2.7	6.4	-1.3	4.3	6.6	1.6	5.6	3.7	6.5	-2.1	3.2	2.3
March	7.0	4.9	9.8	5.4	-0.9	6.4	4.5	8.4	6.9	9.7	9.3	7.2	6.6	6.4
April	12.8	12.2	11.5	11.4	12.0	7.7	12.6	12.6	14.5	11.4	11.9	12.4	11.9	11.7
May	18.0	20.5	16.9	15.6	18.2	17.7	16.4	17.2	19.6	19.0	19.7	20.4	18.3	16.6
June	20.9	20.8	20.9	19.4	21.0	21.7	21.2	20.4	23.4	18.5	22.9	25.2	21.4	20.0
July	23.5	22.2	25.0	25.2	20.4	21.0	22.2	22.5	21.7	21.8	24.1	24.1	22.8	21.8
August	27.8	22.7	24.4	21.2	20.8	21.4	22.6	21.8	25.3	23.9	22.2	26.5	23.4	21.6
September	19.7	17.8	20.6	17.0	13.5	17.8	15.9	20.4	18.4	15.8	17.0	18.9	17.7	17.9
Oktober	12.0	14.1	10.4	14.2	12.7	10.2	13.0	13.8	15.9	15.7	13.0	10.5	13.0	12.6
November	7.2	1.4	9.0	3.4	8.8	6.1	4.1	3.4	10.6	4.9	10.6	9.8	6.6	6.2
December	0.6	2.5	2.9	1.1	-0.8	3.1	-2.2	1.5	3.7	-2.8	1.0	3.0	1.1	2.0
Average year	13.0	11.8	13.1	11.7	10.2	11.3	11.7	12.0	13.7	12.0	13.3	12.9	12.2	11.6
Average vegetation	19.2	18.6	18.5	17.7	16.9	16.8	17.7	18.4	19.8	18.0	18.7	19.7	18.3	17.5

Precipitation (mm)

Month	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	Average period	Average 50 years
January	2	18	50	53	49	46	139	52	37	93	13	66	52	45
February	41	28	14	62	29	54	5	136	34	16	39	39	41	45
March	56	63	48	91	25	20	28	38	74	89	10	16	47	47
April	33	63	101	48	60	86	103	122	47	27	108	13	68	70
May	45	21	34	91	52	65	149	78	60	36	90	45	64	74
June	112	38	65	139	68	115	129	222	36	215	35	20	100	95
July	66	53	64	11	111	138	91	116	56	81	94	68	79	81
August	13	56	141	157	93	72	127	86	46	39	51	27	76	76
September	22	123	81	212	162	20	142	45	34	217	115	29	100	58
Oktober	165	81	59	10	89	106	94	46	30	10	42	142	73	56
November	125	121	27	96	70	32	90	145	73	70	44	56	79	72
December	82	170	79	107	93	90	43	97	43	62	32	23	77	63
Sum of year	762	835	763	1077	901	844	1140	1183	570	955	673	544	854	782
Sum of vegetation	456	435	545	668	635	602	835	715	309	625	535	344	559	510

Number of sunshine hours

Month	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	Average period	Average 50 years
January	76	116	76	43	42	16	120	48	104	56	115	75	74	72
February	133	133	82	136	127	180	185	113	144	132	117	117	133	101
March	158	139	137	84	120	191	211	121	137	167	209	197	156	141
April	185	188	176	172	99	218	162	139	246	210	165	235	183	181
May	267	319	252	199	248	267	259	251	270	212	202	296	254	235
June	220	256	209	160	217	224	184	259	313	184	222	291	228	242
July	287	290	299	297	276	218	247	258	298	266	271	319	277	280
August	341	284	304	270	266	280	253	299	279	273	235	346	286	271
September	240	201	217	135	120	236	123	220	209	129	153	236	185	204
Oktober	110	153	122	188	122	158	120	152	165	194	118	163	147	159
November	93	50	63	61	96	80	66	33	112	128	80	138	83	76
December	50	61	75	18	40	83	62	93	76	89	34	130	68	59
Sum of year	2160	2190	2012	1763	1773	2151	1992	1986	2353	2040	1921	2543	2074	2021
Sum of vegetation	1650	1691	1579	1421	1348	1601	1348	1578	1780	1468	1366	1886	1560	1572

Table 2: Soil parameters in the vineyard in 1990

Ground level (cm)	HYG	Cohesion (KA)	pH (H_2O)	pH (KCl)	$CaCO_3$ (%)	Humus (%)
0-30	1,79	36	7,57	7,35	11,5	1,61
30-60	1,76	36	7,63	7,35	10,8	1,46
Ground level (cm)	NO_3-N (ppm)	P_2O_5 (ppm)	K_2O (ppm)	Ca (ppm)	Mg (ppm)	S (ppm)
0-30	41	484.74	657.23	35052	714.83	36.2
30-60	18	488.47	544.64	33091	621.08	26.5
Ground level (cm)	Na (ppm)	Cu (ppm)	Zn (ppm)	Mn (ppm)	Fe (ppm)	B (ppm)
0-30	12.02	15.36	2.58	62.54	13.51	0.99
30-60	11.18	13.04	2.51	61.71	12.32	0.94
Ground level (cm)	Mo (ppm)	Al (ppm)	Cd (ppm)	Co (ppm)	Pb (ppm)	Ni (ppm)
0-30	0.07	56.7	0.06	1.48	4.34	1.55
30-60	0	56.61	0.09	1.35	3.74	1.52

EUF-1990

Ground level (cm)	UVN	NO_3	P I	P II	K I	K II
0-30	6.58	3.71	4.32	4.37	46.88	27.63
30-60	4.44	1.68	4.06	3.96	32.03	23.38
Ground level (cm)	Ca I	Ca II	Mg I	Mg II	Na I	Na II
0-30	54.31	87.33	1.64	1.54	6.07	1.98
30-60	54.39	81.42	1.51	1.29	5	1.46
Ground level (cm)	Cu	Zn	Mn	Fe	B I	B II
0-30	0.2	2.21	0.11	1.34	0.7	0.45
30-60	0.25	1.87	0.13	2.08	0.51	0.52

Table 3: Soil parameters in the vineyard in 2001

Ground level (cm)	Ca (ppm)	$CaCO_3$ (%)	Humus (%)	NO_3-N (ppm)	P_2O_5 (ppm)	K_2O (ppm)
0-30	2.43	6.07	1.24	18	455	587
30-60	2.70	6.74	1.64	17	658	508
Ground level (cm)	Mg (ppm)	Na (ppm)	Zn (ppm)	Cu (ppm)	Mn (ppm)	Fe (ppm)
0-30	141	40	2.6	17.2	46	30
30-60	149	56	3.4	18.5	54	31
Ground level (cm)	pH (KCl)	pH (H_2O)	Cohesion (KA)	Hy		Sum salt
0-30	7.52	7.68	34	1.83		0.020
30-60	7.52	7.70	34	1.71		0.027

in the leaves at bloom in the case of the rootstock variety '5BB' and its clones Fr.148 and Wei.48 and also in the '5C' clone Gm.6. In spring 'Cabernet Sauvignon' on rootstocks '5C', '5BB' clone Cr.2, '125AA' and 'SO4' had a roughly similar level of boron (approx. 40 ppm; Fig. 1) in the average of twelve years (1992 to

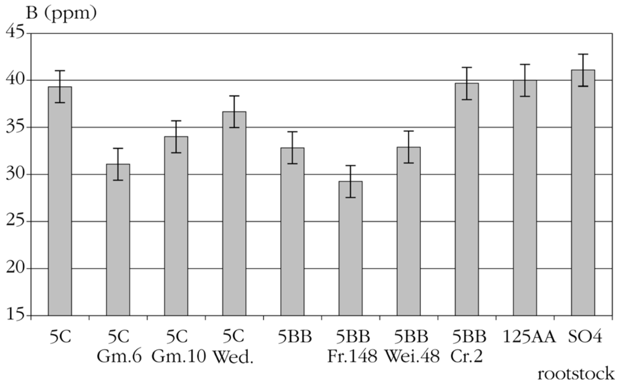

Fig. 1: Boron content of leaves at bloom (on the average of 1992-2003)

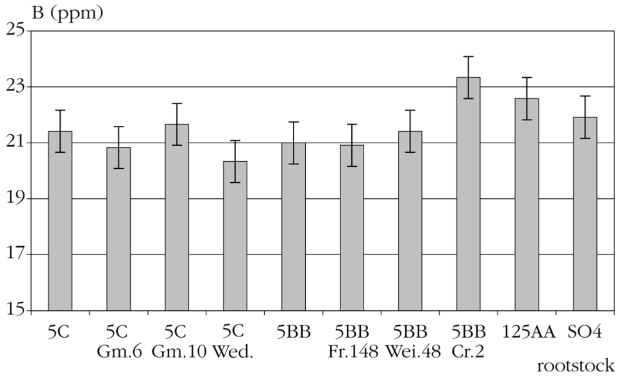

Fig. 2: Boron content of leaves at harvest time (on the average of 1992-2003)

2003). In the case of the rootstocks '5C', '5C' clone Wed., '5BB' clone Cr.2, '125AA' and 'SO4' the decrease of the boron concentration from bloom to ripening is significantly higher than with the other five examined rootstocks. Thus there were minor differences between the rootstocks at ripening.

Wolpert et al. (2005) observed that also in the case of potassium the differences became more moderate between the rootstocks at ripening. According to them these findings suggested that absorption of potassium in spring from bud-break to bloom, may be a more critical period for potassium acquisition, while re-translocation from existing tissues to ripening fruit may represent the primary source for potassium during the ripening period.

In autumn only the rootstock '5BB' clone Cr.2 showed a significantly higher value compared to those having low concentrations of boron at bloom, and the lowest value was measured with the rootstock '5C' clone Wed (Fig. 2.). Similarly to the results of Bogoni et al. (1995)

Table 4: Yield quantity (kg/stock) of ’Cabernet Sauvignon’ grafted on different rootstocks

Rootstock	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	average
5C	5.775	4.750	4.575	3.975	4.025	4.650	5.200	2.700	3.475	4.075	4.150	3.650	4.250
5C Gm.6	4.450	4.950	4.725	3.775	3.400	4.500	6.125	2.525	4.850	4.950	4.300	3.200	4.313
5C Gm.10	5.400	4.325	4.750	3.750	4.325	5.000	5.825	2.625	3.725	5.850	3.125	3.425	4.344
5C Wed.	4.550	4.425	4.825	3.275	3.750	4.150	5.800	2.675	3.875	5.850	3.850	3.825	4.238
5BB	4.050	4.175	4.375	3.575	3.550	4.875	6.200	2.600	4.775	5.050	3.775	4.150	4.263
5BB Fr.148	4.050	3.550	4.125	3.000	3.875	3.750	5.725	2.325	4.025	4.000	3.650	3.050	3.760
5BB Wei. 48	4.000	4.225	3.750	3.225	3.575	4.600	5.225	2.350	3.825	4.400	4.325	3.475	3.915
5BB Cr.2	5.100	4.950	5.025	3.375	3.650	4.125	5.900	2.500	3.500	5.325	3.350	2.825	4.135
125 AA	4.575	4.400	4.325	3.375	3.775	4.375	7.375	2.450	3.950	4.650	3.600	3.900	4.229
SO4	6.350	5.100	5.000	3.400	3.975	4.725	5.975	3.100	4.475	4.100	3.525	3.450	4.431
average	4.830	4.485	4.548	3.473	3.790	4.475	5.935	2.585	4.048	4.825	3.765	3.495	4.188
LSD	1.3390						0.9482			1.2451			
p	0.017	NS	NS	NS	NS	NS	0.009	NS	NS	0.033	NS	NS	

we observed a vintage effect on the concentration of boron, mainly at ripening. Kocsis et al. (2001) pointed out the role of dry conditions in nutrient uptake. Csikászné et al. (2003) observed a significant vintage effect on the uptake of nutrients but comparing the rainy and the dry vintages they found no close connection between the nutrient content of the leaves and the moisture content of the soil. Therefore, we divided the examined years into two groups but not according to the character of the vintage, rather according to the nutrient levels measured at ripening. We did the calculations separately for the two different groups and in the years which showed optimum levels in autumn we have still found significant differences between the rootstocks, which corresponds to the results of the whole experiment. The two-way analysis of variance carried out in the years with boron deficiency at ripening showed no significant difference between the rootstocks. Based on the found tendency, the rootstocks can be divided into two groups; higher values were found in leaf samples on rootstock ’5 BB’ clone Cr. 2, ’125AA’ and ’SO4’, while the other rootstocks represented the lower level.

Rootstock effect on boron content of the must

During the twelve years of the experiment the boron content of the must was also determined. According to Kocsis and Podmaniczky (2005) the nutrient content of the must varied between rootstocks as well as scion combinations, too. In our experiment, we could not find a statistically proven difference between the 12-years average values of the examined rootstocks. Looking at the individual years, however, the following tendency can be detected:

The rootstock ’5C’ clone Wed., which showed the lowest boron concentration in leaves at ripening had also the lowest boron content in the must. The rootstock ’5BB’ clone Cr.2 which showed a significantly higher boron concentration in leaves at ripening had a similarly high boron value in the 12-year average. Otherwise the rootstock ’5C’ clone Gm.10 exhibited a high boron content in the must but did not have extreme boron values in the leaves during any time of the vegetation period (Fig. 3.). Polyák et al. (1992a, 1992b) determined 28 elements in musts from the cultivars ’Hárslevelű’ and ’Furmint’ on 36 different rootstocks. According to their analytical data different rootstock varieties took up the element from the soil with different capacity. With regard to essential elements (like K, N, P, Mg, B, Zn) there is scarcely a difference between rootstocks.

Rootstock effect on the crop load

The rootstock effect on the yield was significant in three years (1992, 1998, 2001). The yield per plant and

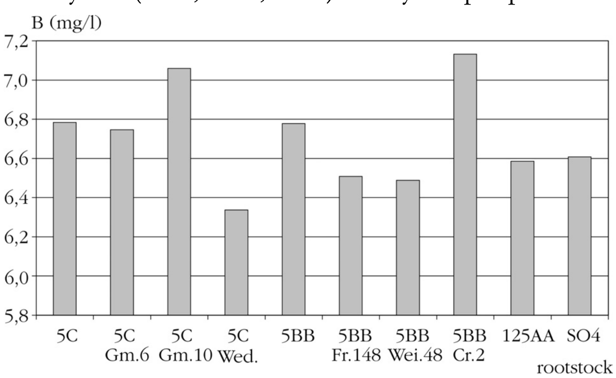

Fig. 3: Boron content of the must (on the average of 1992-2003)

Table 5: Must degree (Brix) of 'Cabernet Sauvignon' grafted on different rootstocks

Rootstock	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	average
5C	21.1	23.0	23.0	22.3	20.7	22.2	19.9	23.4	24.8	23.3	24.7	25.7	22.83
5C Gm.6	21.4	22.5	23.2	22.6	20.5	22.8	20.4	23.3	24.5	24.0	24.1	26.3	22.97
5C Gm.10	20.5	22.5	23.1	22.4	20.4	22.4	20.3	23.0	24.6	23.8	24.0	26.0	22.75
5C Wed.	20.9	22.4	23.0	22.7	20.7	22.6	19.8	23.4	24.8	23.6	24.5	26.2	22.89
5BB	20.8	21.9	22.8	22.4	20.3	22.7	19.8	23.1	24.4	23.8	24.0	25.4	22.61
5BB Fr.148	20.8	22.5	22.9	22.7	20.6	22.9	20.0	23.5	24.5	24.0	24.3	26.1	22.90
5BB Wei. 48	21.0	22.3	23.2	22.4	20.7	22.5	20.2	23.2	24.0	23.8	24.3	25.3	22.75
5BB Cr.2	21.4	23.2	23.1	22.7	20.6	23.0	20.2	23.2	24.7	24.4	24.1	26.1	23.06
125 AA	21.2	22.8	22.9	22.7	20.4	22.8	20.0	23.1	24.2	24.1	24.5	25.8	22.88
SO4	20.7	22.3	22.9	22.7	19.9	22.5	20.0	23.3	24.1	23.5	24.1	25.4	22.60
average	20.99	22.54	23.02	22.56	20.47	22.64	20.06	23.24	24.45	23.83	24.26	25.83	22.82
LSD	0.590	0.420							0.525	0.530			
p	0.078	0.00	NS	NS	NS	NS	NS	NS	0.05	0.02	NS	NS	

the age of the vineyard were different in each case. In the first case in 1992, when the plants were still young and the yield was similar to the year 2001, we found that the rootstock 'SO4' and '5C' had the highest crop level. These rootstocks usually yielded more than the average of the examined rootstocks (Table 4.). Productivity of 'SO4' decreased in the last three years, which corresponds well with the findings of Candolfi-Vasconcelos et al. (1997), who reported that the vigour of 'SO4' decreases after 15 to 20 years. Except the rootstocks 'SO4' and '5C' the other rootstocks yielded the highest crop in 1998. In this year the '125AA' showed unexpectedly the highest value, which in the next year produced the lowest yield. In ten years of the examined twelve years the rootstock '5BB' clones Fr.148 and Wei.48 yielded below the average level of the experiment, the '5BB' rootstock, however, performed below average only in four years at the beginning of the examined period.

Pruning weight data only showed significant differences between rootstocks in two years (1995 and 1999.). We got the highest pruning weight on the rootstocks '5BB' and its Cr.2 clone.

Rootstock effect on the quality parameters

The rootstock had significant effects not only on the quantity parameters but also on the must weight in the years 1992 and 2001 (Table 5.). In these years the average crop level was the same, but the sugar content of the must was higher in 2001. In 2001 the rootstocks '5C' and 'SO4' did not show only a lower yield, but the lowest sugar accumulation as well. In 2001 the clones Gm.6 and Gm.10 of the rootstock variety '5C' and the Cr.2 clone of '5BB' showed significantly higher yield and sugar content, too. In the unfavourable vintage year 1992 the rootstocks '5C' clone Gm.6 and '5BB' clone Cr.2 performed well, just like in 2001, but the sugar content of the must on the rootstock '5C' clone Gm.10 was the lowest in this year. In the good vintages of 2000 and 2003, the sugar accumulation remained below average on the following rootstocks: '5BB', '5BB' clone Wei.48., '125AA' and 'SO4'.

Among the quality parameters the titratable acidity contents showed significant differences between rootstocks (Table 6.) in most of the years (1992 to 1996, 1999 to 2000).

In 1992 the highest sugar value was measured on rootstocks 'SO4' and '5BB' clone Cr.2. The '5BB' rootstock had the lowest titratable acidity in this year. In the year 2000 with an accelerated ripening, the titratable acidity content of must was lower on rootstocks '5C' and its clones and on '5BB'. Looking at the whole period of the experiment in most of the cases the musts from rootstocks '5C' clones Wed. and Gm.6 and '5BB' showed relatively low values of titratable acidity, while the must of rootstocks 'SO4' and '5BB' clone Cr.2 had relatively high levels.

Correlation Analysis

As the contents of mineral elements of the musts were different depending on rootstocks, Polyák et al. (1992a) supposed, that the quality of wines is considerably modified by scion combinations and especially by rootstock varieties.

During the assessment of our experiment results, we examined the correlations between the boron concentrations in the leaves or the musts and the other examined nutrient or crop parameters. We found a positive correlation between the boron concentrations of the leaves and the titratable acidity of the musts (Fig. 5.).

Table 6: Titratable acidity content (g/l) of 'Cabernet Sauvignon' grafted on different rootstocks

Rootstock	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	average
5C	9.2	9.2	8.7	11.2	13.5	10.4	12.7	12.0	8.6	11.3	11.1	9.1	10.58
5C Gm.6	9.2	9.4	8.1	12.1	13.5	10.0	11.8	11.6	9.0	11.1	11.5	9.0	10.50
5C Gm.10	9.3	9.5	8.2	12.0	13.9	10.3	11.4	11.4	8.8	11.4	11.7	8.9	10.56
5C Wed.	9.2	9.7	7.8	11.0	13.2	10.2	11.5	11.6	8.9	11.2	11.9	8.8	10.39
5BB	9.0	9.5	7.9	11.3	13.7	10.1	11.5	11.8	8.9	11.8	11.8	8.9	10.50
5BB Fr.148	9.3	9.0	7.7	11.1	13.7	10.2	11.7	12.2	9.4	12.5	11.6	8.9	10.60
5BB Wei. 48	9.1	9.4	7.6	11.6	13.8	10.4	11.6	12.2	9.2	11.4	11.1	8.8	10.51
5BB Cr.2	9.5	9.2	8.3	11.0	14.1	10.6	11.7	12.2	9.2	10.7	11.8	9.1	10.60
125 AA	9.3	9.4	7.7	11.0	12.8	10.6	11.5	12.1	9.3	11.1	11.3	8.8	10.39
SO4	9.8	9.8	8.1	11.9	12.9	10.4	11.1	12.5	9.1	11.7	11.9	8.7	10.64
average	9.28	9.39	7.99	11.41	13.49	10.33	11.64	11.96	9.04	11.41	11.54	8.87	10.53
LSD	0.44	0.31	0.58	0.79	0.84			0.71	0.40				
p	0.08	0.00	0.02	0.03	0.08	NS	NS	0.099	0.02	NS	NS	NS	

Table 7: Boron content in the leaf blades (ppm) and in the must (mg/l)

Rootstock	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003
Leaves at blooming												
5C	31	28	31	35	57	40	49	49	44	26	39	43
5C Gm.6	23	23	28	25	39	26	35	40	38	36	32	28
5C Gm.10	26	23	30	33	48	33	39	44	41	29	34	28
5C Wed.	25	26	32	31	57	34	43	56	39	27	39	31
5BB	22	24	30	29	44	31	54	36	34	25	27	38
5BB Fr.148	25	22	24	23	40	26	36	37	33	28	28	29
5BB Wei. 48	25	26	28	28	46	24	36	42	35	24	47	34
5BB Cr.2	33	32	36	44	51	33	51	52	37	36	35	36
125 AA	31	27	30	34	62	38	54	55	43	31	41	34
SO4	32	30	32	35	61	35	54	58	45	31	40	40
average	27	26	30	32	51	32	45	47	39	29	36	34
Leaves at ripening												
5C	13	17	20	28	19	17	28	23	19	23	29	21
5C Gm.6	15	19	20	25	17	16	23	24	22	23	24	22
5C Gm.10	15	18	20	28	19	18	26	24	20	22	26	24
5C Wed.	16	18	17	27	20	17	22	21	21	20	24	21
5BB	15	19	18	28	20	16	25	23	19	21	26	22
5BB Fr.148	14	18	20	25	19	17	23	24	19	23	26	23
5BB Wei. 48	13	20	20	25	20	15	24	22	19	28	27	24
5BB Cr.2	16	20	20	27	27	17	27	27	21	28	24	26
125 AA	15	19	19	31	29	15	26	25	21	23	25	23
SO4	14	20	19	29	28	17	26	24	18	22	24	22
average	15	19	19	27	22	17	25	24	20	23	26	23
Must												
5C	3.74	5.07	10.60	7.99	8.01	7.12	4.90	8.75	7.11	4.45	5.75	7.91
5C Gm.6	4.05	3.75	7.78	6.71	6.67	7.74	5.26	9.48	7.11	5.19	5.17	12.05
5C Gm.10	3.74	2.42	8.48	8.63	7.34	7.74	5.98	9.48	7.80	5.19	6.67	11.24
5C Wed.	4.35	2.42	7.07	7.99	6.00	6.19	5.98	8.75	7.11	2.96	5.17	12.05
5BB	3.14	3.74	8.84	7.99	6.00	7.74	5.26	8.75	7.11	4.45	6.79	11.52
5BB Fr.148	4.05	2.42	7.77	7.99	6.00	6.50	4.90	8.75	8.50	2.96	5.46	12.80
5BB Wei. 48	3.74	2.75	7.05	7.99	7.34	6.19	5.62	9.48	7.11	2.96	4.87	12.76
5BB Cr.2	4.96	2.42	8.48	9.92	7.34	7.74	5.62	10.94	8.50	3.70	5.02	10.94
125 AA	4.66	2.42	8.84	7.35	6.00	8.36	6.71	6.56	7.80	5.19	6.64	8.50
SO4	4.05	2.42	7.77	7.99	6.67	8.67	6.35	7.29	7.80	3.70	6.49	10.10
average	4.05	2.98	8.27	8.06	6.74	7.40	5.66	8.82	7.60	4.08	5.80	10.99

Table 8: Nitrogen content in the leaf blades (dw %) and in the must (mg/l)

Rootstock	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003
Leaves at blooming												
5C	3.91	3.88	4.05	3.77	4.76	4.11	4.31	4.10	4.16	3.61	4.16	5.24
5C Gm.6	3.75	4.05	4.20	3.73	4.73	3.93	4.24	4.25	4.03	3.63	4.48	4.29
5C Gm.10	3.85	3.84	3.70	3.71	4.82	4.07	4.44	4.33	3.99	3.67	4.18	4.38
5C Wed.	3.76	4.18	3.97	3.76	4.89	3.87	4.16	4.28	4.14	3.45	4.11	4.20
5BB	3.94	4.10	3.91	3.79	4.87	4.08	3.90	4.10	4.20	3.80	4.28	4.39
5BB Fr.148	4.11	3.80	3.82	3.60	4.77	3.99	4.30	4.32	4.15	3.62	4.38	4.26
5BB Wei. 48	3.96	4.09	3.89	3.88	4.85	3.95	4.05	4.29	4.29	3.49	4.47	4.29
5BB Cr.2	3.83	4.01	3.95	3.74	4.26	3.34	4.27	4.25	4.17	3.67	4.11	4.12
125 AA	3.75	3.88	3.87	3.63	4.82	3.84	4.13	4.16	3.99	3.60	4.26	4.35
SO4	3.63	3.95	3.88	3.71	4.81	3.75	4.03	4.35	4.13	3.50	4.11	4.35
average	3.85	3.98	3.92	3.73	4.76	3.89	4.18	4.24	4.13	3.6	4.25	4.39
Leaves at ripening												
5C	2.33	1.84	2.11	2.35	2.14	2.31	2.01	2.46	2.20	2.26	2.53	2.29
5C Gm.6	2.14	1.95	2.22	2.53	2.19	2.26	1.96	2.42	2.28	2.09	2.14	2.76
5C Gm.10	2.25	1.93	2.25	2.38	2.09	2.43	1.94	2.64	2.28	2.17	2.41	2.42
5C Wed.	2.24	1.98	2.25	2.31	2.10	2.36	2.07	2.45	2.26	2.22	2.09	2.69
5BB	2.23	1.92	2.20	2.46	2.16	2.34	2.01	2.48	2.40	2.32	2.69	2.37
5BB Fr.148	2.26	1.87	2.15	2.31	2.06	2.22	2.04	2.56	2.30	2.32	2.31	2.65
5BB Wei. 48	2.31	1.95	2.13	2.43	1.99	2.17	2.09	2.42	2.23	2.29	2.66	2.63
5BB Cr.2	2.26	1.85	2.11	2.30	2.06	2.14	1.96	2.40	2.05	2.08	1.99	2.25
125 AA	2.27	1.96	2.28	2.32	2.26	2.21	2.14	2.50	2.13	2.31	2.39	2.37
SO4	2.19	1.95	2.22	2.36	2.15	2.19	2.13	2.58	2.02	2.12	2.10	2.42
average	2.25	1.92	2.19	2.38	2.12	2.26	2.04	2.49	2.22	2.22	2.33	2.49
Must												
5C	504	520	667	661	834	509	567	509	765	786	694	726
5C Gm.6	523	478	636	692	834	496	587	553	664	781	744	624
5C Gm.10	493	439	625	717	774	465	567	486	678	843	825	759
5C Wed.	537	450	636	671	817	465	588	512	654	776	802	468
5BB	523	464	630	656	790	452	583	499	688	862	827	850
5BB Fr.148	590	439	597	635	768	458	635	558	678	829	843	796
5BB Wei. 48	548	408	608	681	752	429	573	532	608	833	820	834
5BB Cr.2	562	453	625	717	719	490	627	548	712	710	832	710
125 AA	543	495	636	728	703	475	624	525	664	814	834	759
SO4	493	456	647	681	693	448	573	517	606	753	772	716
average	532	460	631	684	768	469	592	524	672	799	799	724

Correlation was negative between must weight and boron concentration of the leaves at bloom, and between must weight and the changing of boron content from blooming to ripening.

Out of the other eight examined nutrients (N, P, K, Ca, Mg, Zn, Fe, Mn) nitrogen had the highest effect on the boron values (Table 8, Fig. 4.). We found correlations at bloom between the boron and nitrogen concentrations of the leaves, moreover, the changes in the boron and nitrogen concentrations of the leaves showed a positive correlation. This correlation coincides with the findings of CAMACHO-CRISTÓBAL and GONZÁLEZ-FONTES (1999). According to them the reduced nitrogen uptake in boron deficient vines leads to low leaf nitrogen status, sugar and starch accumulation in the leaves. We found a correlation between the nitrogen content of the leaves at ripening and the boron content of the must. Evaluating the latter correlation for each rootstock, the following rootstocks showed a significant effect: the clones of '5C', the clone '5BB' Fr.148 and Cr.2 and 'SO4'.

Between the boron content of the must and the quantitative and qualitative parameters of the crop we also obtained a good correlation (r-values of 0.4 to 0.5). We suppose that in the background of these correlations there is the hidden boron partitioning between grapes, leaves and woody parts, which is similar to partitioning of nitrogen, phosphorus and potassium. This means that more than one third of the quantity of the total element is found in the grapes (FÜLEKY, 1999). ROGIERS et

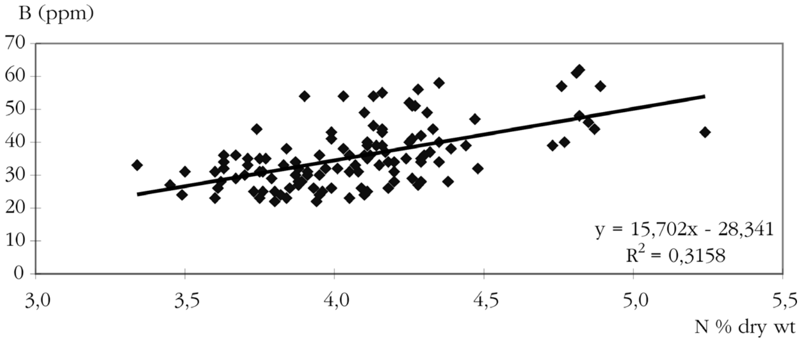

Fig. 4: Relations between N and B concentrations in leaves at bloom

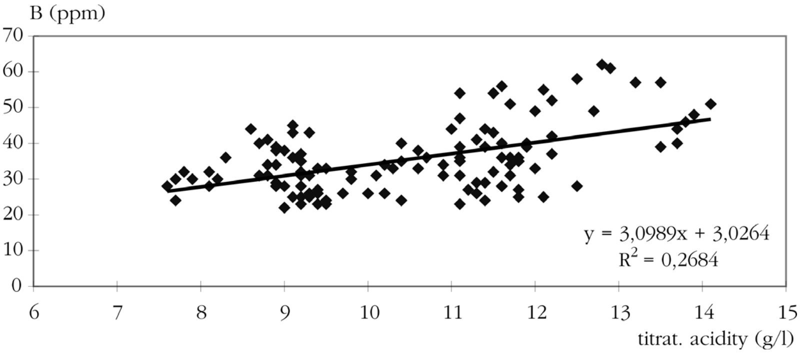

Fig. 5: Relations between leaf B content at bloom and titratable acidity of the must

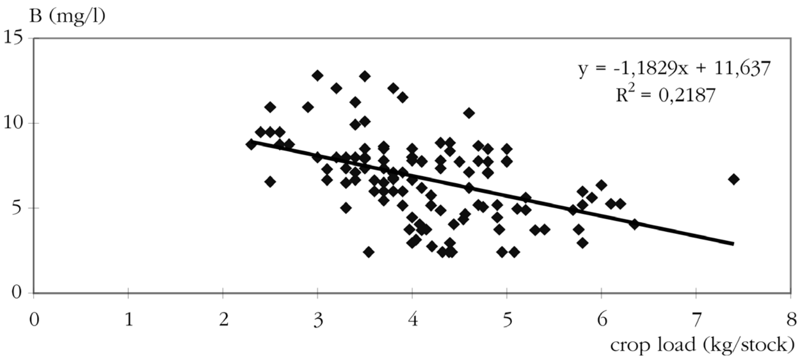

Fig. 6: Relations between B content of the must and crop load of the stocks

al. (2006) demonstrated that 90 days after flowering boron partitioning into tissues showed similar ratios as potassium. At this time the pulp contained 59% of the total potassium amount in the berry, while the skin contained 32%, and the seeds contained 6% of the total amount of that element in the berry. These findings refer to the importance of must analysis in the case of boron, because the highest rate of total amount is found in the must. We found a positive correlation between boron content of the must and the must weight, as well as the pH-value of the must (the latter was only determined in eight years of the examined period). This result corresponds with conclusions of CLINGELEFFER (2000), who reported that rootstock selections which have high concentrations of calcium, magnesium and boron in berries tended to have higher sugar levels. We found a negative correlation between the boron content of the must and yield, yield to pruning weight ratio (Razav index), respectively (in the period from 1992 to 2001, Fig. 6).

CANDOLFI-VASCONCELOS et al. (1997) examined the nutrient uptake of certain rootstocks in a habitat with boron deficiency. They found that the most excellent rootstocks with regard to boron uptake had a reliable performance at all the four sites examined.

Conclusion

Our results draw attention to the importance of boron in quantitative and qualitative parameters of yield and the correlation between the boron and nitrogen concentrations in leaves. The boron uptake and transport of 'Cabernet Sauvignon' varies with rootstock-scion combinations. The behaviour of the rootstock clones particularly that of the rootstock '5BB' clone Cr.2 is characteristic for a given site. Vintage definitely had effect on the nutrient content of leaves.

Boron concentration in leaves at bloom had effect on quality parameters (titratable acidity, must weight) of the must. The correlation was positive between the boron content of the leaves and titratable acidity, and negative with must degree. A positive correlation between boron content of the must and the must weight was found.

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