EFFECTS OF ROOTSTOCK-SCION COMBINATIONS ON MACROELEMENTS AVAILABILITY OF THE VINES
ALANY-NEMESFAJTA KOMBINÁCIÓK HATÁSA A SZŐLŐ MAKROELEM FELVÉTELÉRE

Anna CSIKÁSZ-KRIZSICS*, Lajos DIÓFÁSI

Research Institute for Viticulture and Oenology, Pécs, H-7634 Pécs, Pázmány P. u. 4.,
phone: (36) 72-517-930; fax: (36) 72-517-936; e-mail: krizsics.anna@szbki-pecs.hu

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ABSTRACT

This study investigates macroelement contents (N, P, K, Ca, Mg) and their quality relations of 4 scion grape varieties (Italian Riesling, White Riesling, Chardonnay, Cabernet sauvignon) on 6 rootstock varieties (5C, 5BB, 125AA, 140Ru, 110R, Fercal) between 2001 and 2005. A field experiment was set up at Szentmiklós Hill (on the border of the town of Pécs) in southern part of Hungary in 1999. The investigated rootstocks had no statistically proven effect on the nitrogen levels of the leaves, but the scion varieties had. Phosphorus content of the leaves on rootstocks with Berlandieri x Riparia genetic background (5C, 5BB, 125AA) was lower at blooming than that on other investigated rootstocks. We found statistically significant differences in the calcium and magnesium content of leaves regarding rootstock and scion varieties too.

KEYWORDS: grapevine, rootstock varieties, soil and leaf analysis, macronutrients, nutrient ratios

ÖSSZEFOGLALÓ

A tanulmány 4 nemes szőlőfajta (Olasz rizling, Rajnai rizling, Chardonnay, Cabernet sauvignon) és 6 alanyfajta (5C, 5BB, 125AA, 140Ru, 110R, Fercal) kombináció esetében vizsgálja a levelekben a makroelemek koncentrációjának alakulását (2001-2005. között) és ezek minőségi viszonyát.

A szabadföldi kísérlet Szentmiklós –hegyen (Pécs város határában) Magyarország déli részén 1999-ben került beállításra. A vizsgált alanyfajtáknak nem volt hatása a levelek N tartalmára, de a nemes fajtáknak igen. A Berlandieri x Riparia genetikai hátterű alanyokon a levelek foszfor tartalma virágzáskor alacsonyabb volt, mint a többi vizsgált alanyfajtán. Mind virágzáskor, mind éréskor a levelek kalcium és magnézium tartalma között statisztikai számításokkal igazolt különbség mutatkozott alanyonként és nemes fajtánként is.

KULCSSZAVAK: szőlő, alanyfajták, talaj-és levélanalízis, makroelemek, tápelem arányok

DETAILED ABSTRACT IN HUNGARIAN

A fenntartható termelés számára fontos az alanyok, a különböző talajjellemzők és a nemes teljesítménye közötti kölcsönhatások ismerete. Ugyanaz az alany eltérő hatást mutathat a nemes fajták makroelem tartalmára, másrészt a különböző alanyfajták a nemes fajták különböző reakcióit eredményezhetik. A talajsajátosságoknak megfelelő alany-nemes kombináció választása esetén a trágyázás mérsékelhető vagy el is hagyható és kedvezőbb egyensúly hozható létre a vegetatív- és termésprodukció között.

A fürttermés optimális ásványi tápelem ellátottsága nincs összefüggésben a levél optimális tápelem szintjével, de a levél optimális tápelem ellátottsága fontos a terméshez és a magas növény hatékonysághoz.

A szabadföldi kísérleteti ültetvényünk térállása 2,2 x 0,8 m (sortáv x tőtáv), a művelésmód közép-magas kordon. Az ültetvény Permi homokkő alapon képződött barna erdőtalajon került eltelepítésre.

A területről a telepítés előtt vett talajminták foszfor és kálium tartalma a hagyományos eljárás (aluminium-laktátos kivonat) mellett EUF-módszerrel is meghatározásra került (1-2. táblázatok).

A 4 nemesfajta makroelem tartalmát 6 alanyfajtán faktoriális elrendezésben 5 éven át vizsgáltuk (2001-2005). A makroelem koncentrációkat virágzáskor és éréskor vett levéllemez mintákból analizáltuk.

Kísérletünk célja fiatal ültetvényben alany-nemes kombinációk tápelem hasznosító képességének megismerése adott termőhelyi viszonyok között.

A vizsgált alanyoknak nem volt statisztikai számításokkal megerősített hatása a levelek N szintjére, de a nemes fajtáknak igen. Valamennyi alanyfajtán 5 év átlagában a Cabernet sauvignon N szintjei voltak a legmagasabbak virágzás idején, ez a fajta erőteljes növekedésének tudható be (3.táblázat).

A levelek P tartalma virágzáskor a Berlandieri x Riparia genetikai háttérrel rendelkező alanyokon alacsonyabb volt, mint a többi vizsgált alanyfajtán, viszont érés idejére a levelek P tartalma vonatkozásában az egyes alanyok pozíciója megváltozott (1.ábra). A 140Ru és Fercal alanyokon lévő szőlő leveleinek P tartalma alacsonyabb lett a nemes fajták átlagában, mint a Berlandieri x Riparia származású alanyoké, elsősorban az 5C-é.

A levelek kálium tartalmában szignifikáns különbséget a nemes fajták szerint csak virágzáskor figyeltünk meg, ha ismétlésnek az éveket tekintettük (4.táblázat). Az Olasz rizling fajta értékei szignifikánsan magasabbak mint a Chardonnay-é és a Cabernet sauvignon-é. Míg a nemes fajták Ca és Mg felvételében azonos tendencia látszik, addig az alanyfajták viselkedése e két tápelem felvétele tekintetében antagonisztikus (2-5.ábra).

A tápelemarányok alakulásában a legnagyobb különbség az 5 vizsgált évből a pozitív kiugró értéket mutató évben mutatkozott, míg a negatív szélső értéket mutató években a legkisebb az alanyok közötti eltérés. Ez összefüggésben lehet azzal, hogy az alanyok tápelem felvételének sajátosságai szélsőséges évjáratokban és korlátozott tápelem szolgáltatás mellett mutatkoznak meg leginkább.

INTRODUCTION

For sustainable viticulture, it is important to know the interactions among rootstocks, different soil characters and production of scions [12]. The same rootstock may have different effect on the macroelement content of scion varieties; on the other hand the different rootstock varieties can give rise to different reactions of scion varieties [9]. In case of adjusted rootstock-scion combination to soil character, the fertilization would be decreasable or abandonable and the better balance between vegetation and production should be found.

Optimal fruit mineral nutrition does not correspond with optimal leaf mineral nutrition, but optimal leaf mineral nutrition is important for yield and high plant efficiency [7].

The absorption of water and nutrients happen through the roots of the stocks and depends on several factors such as the root structure (morphological and physiological features), the soil (availability of water and nutrients, temperature etc.) and the above-ground parts of vines (ability of photosynthesis and transpiration). These three factors interact with each other more or less and they are influenced by climate, techniques of cultivation and possible pathogens [20]. Grafting modifies the mineral content of above-ground parts of vines, where both the rootstock and the scion as well play an important part [6].

Vercesi [20] characterizes the rootstock's mineral absorption ability on the grounds of their genetic background. The rootstocks with a Berlandieri x Riparia genetic background (5C, 5BB, 125AA) can be characterized as having a good ability of Ca, P, Mg absorption and a reduced ability in case of K. Rootstock with Berlandieri x Rupestris genetic background (140Ru, 110R) generally have a good ability of nutrient uptake with an increased K uptake and a weaker Mg, Ca uptake ability. In case of the rootstocks with a Berlandieri x Vinifera genetic background (Fercal), there is a good ability of K and Mg uptake, but the utilization of Ca is weak. Miklós [15] in her Ca transport research ranked the varieties on the basis of the leaves' Ca content: there are exclusives, accumulatives, and intermediaries. According to her, the Ca content of leaves and the K/Ca ratio might be in connection with the lime susceptibility/ tolerance.

The aim of our experiment is to determine the nutrient uptake ability of rootstock-scion combinations in not or under yielded vineyards at a certain location under given circumstances.

MATERIAL AND METHOD

A field experiment was set up at Szentmiklós Hill (on the border of the town of Pécs) in southern part of Hungary in 1999. Vineyard spacing was 2,2 x 0,8m (row x vine), and the row orientation was droop, with a north-south direction. The training system was middle-high cordon. The experimental vineyard was placed 230-260 meters above sea-level. The vineyard is planted on brown forest-soil bordered by a solid Perm's sandstone from below.

Phosphorus and potassium content of soil samples from the field of the vineyard taken before planting was measured not only by traditional method (AL- extract) but with EUF-method too.

Macroelement contents (N, P, K, Ca, Mg) of 4 scion-grape-varieties (Italian Riesling P.2 clone, White Riesling Ni.378 clone, Chardonnay C.166 clone, Cabernet sauvignon E.153 clone) on 6 rootstock varieties (5C, 5BB, 125AA, 140Ru, 110R, Fercal) were investigated by factorial design over five years (2001-2005). The macroelement concentrations were measured from leaf blades of 30 plants per rootstock x scion combinations at blooming and ripening periods. The samples was taken opposite the cluster. The leaf blades were washed in distilled water, dried and ground. The concentrations of elements were determined according to standard methods, where N was determined by Kjeldahl-method. Phosphorus content of the leaves was measured by spectrophotometer using standard row. The determination of K, Ca and Mg elements was done by atomic absorption spectrometry. Concentrations were expressed as a percentage of total dry mass. The results were evaluated by the two-way ANOVA. To evaluate the rootstock effect, in one case the years were considered as repetition, in the other case the scions.

RESULTS AND DISCUSSION

Results of soil analysis

The soil of the field is slightly leached, with scarce of calcium and with low sand-adherence value. The upper soil has slight humus content, while the lower soil is poor in it and has weak nitrogen content as well.

The nitrogen, phosphorus and potassium values of the soil – determined from AL-extract – are very high, especially on grounds of adherence values (Table1). According to the EUF method, the field's phosphorus supply is satisfactory, while in case of potassium it would require 160 kg of K_2O fill up (Table 2).

The soil and leaf analysis results show in several cases a contradiction regarding the supply of given nutrients, which fact corresponds with publications [10, 17], which states that there is a slight correlation between the P and K supply of the soil and the nutrient contents of the leaves.

Results of leaf analysis

Nitrogen

Nitrogen levels at blooming were in optimum or high range (moreover in Cabernet sauvignon the measured value was very high in 2005) but by the time of ripening these levels decreased to low or optimum range. The investigated rootstocks had no statistically proven effect on the leaves' nitrogen level, but the scion varieties had.

This corresponds with the statement of Sarič et al. [18], that N uptake and content was influenced more by scions than rootstocks.

Among all rootstock varieties in the average of 5 years Cabernet sauvignon had the highest N levels at blooming period, it is in connection with the high vigour of this variety (Table 3). At ripening only the Cabernet sauvignon's and the Chardonnay's values were in optimum range. In general, N levels declined significantly between

Table 1. Results of soil analysis
1.táblázat. A talajanalízis eredményei

Treatment	Depth	pH_{H2O}	pH_{KCl}	K_A	H%	NO_3N	$CaCO_3$	hy1	P_2O_5	K_2O	Mg
										mg/kg	
Italian Riesling	0-30 cm	6,77	5,30	25,0	1,16	3,00	3,60	1,20	211,1	423,8	117,5
	30-60 cm	6,52	6,02	25,5	0,82	2,00	3,00	1,20	134,9	314,6	151,8
Cabernet sauv.	0-30 cm	6,01	5,57	25,0	1,08	1,25	4,65	1,15	233,1	445,9	132,5
	30-60 cm	6,59	6,21	24,5	0,99	1,00	3,40	1,15	216,8	366,8	125,1
average		**6,47**	**5,77**	**25,0**	**1,01**	**1,81**	**3,66**	**1,18**	**199,0**	**387,8**	**131,7**

Table 2. Results of soil analysis by EUF-method
2.táblázat. Talajvizsgálati eredmények - EUF módszerrel

Treatment		Phosphorus			Potassium*		
	Depth	P 20°C	P 80°C	P 80/20	K 20°C	K 80°C	K 80/20
Italian Riesling	0-30 cm	2,33	0,69	0,296	16,6	4,57	0,275
	0-30 cm	2,67	0,56	0,210	13,9	3,75	0,270
	30-60 cm	1,41	0,33	0,234	10,7	3,84	0,359
	30-60 cm	2,57	0,58	0,226	6,21	3,43	0,552
	average	**2,245**	**0,54**	**0,241**	**11,8525**	**3,8975**	**0,364**
Cabernet sauv.	0-30 cm	3,22	0,83	0,258	15,5	5,36	0,346
	0-30 cm	2,45	0,83	0,339	13,4	3,94	0,294
	30-60 cm	1,8	0,53	0,294	9,37	4,12	0,440
	30-60 cm	2,75	0,55	0,200	9,29	3,16	0,340
	average	**2,555**	**0,685**	**0,273**	**11,89**	**4,145**	**0,355**
	optimal value	~ 2,25			~ 15,0		

* K clay mineral content was 10%

Table 3. Nitrogen results of leaf analysis (d.w.%)
3. táblázat. A levélanalízis eredményei - Nitrogén sz.a.%

	2001		2002		2003		2004		2005	
Scion	blooming	ripening	blooming	ripening	blooming	ripening	blooming	ripening	blooming	ripening
Italian Riesling	3,58	1,38	3,49	1,69	3,29	2,21	3,23	1,77	3,85	2,07
White Riesling	3,46	1,32	3,37	1,30	3,04	2,10	3,08	1,99	3,70	1,87
Chardonnay	3,59	1,40	3,46	1,91	3,19	2,20	2,97	2,31	3,71	2,25
Cabernet sauvignon	3,66	1,85	3,76	2,10	3,68	2,39	3,49	1,73	4,34	2,32
Average	3,573	1,488	3,520	1,750	3,300	2,225	3,193	1,950	3,900	2,128
Significance [a]	*	***	**	***	***	*	***	***	***	***
LSD	0,137	0,135	0,235	0,136	0,272	0,200	0,206	0,171	0,306	0,221

a : * , **, ***, ns : Main effects significant at P< 0,05, P< 0,01, P< 0,001, or not significant, respectively.

Table 4. Potassium results of leaf analysis (d.w.%) at blooming
4. táblázat. A levélanalízis eredményei virágzáskor - Kálium sz.a.%

Scion	2001	2002	2003	2004	2005
Italian Riesling	1,44	1,70	1,30	1,51	1,39
White Riesling	1,49	1,46	1,24	1,54	1,40
Chardonnay	1,53	1,32	1,12	1,99	1,12
Cabernet sauvignon	1,65	1,48	1,15	1,07	1,37
Average	1,528	1,490	1,203	1,528	1,320
Significance [a]	ns	*	***	***	*
LSD	0,200	0,255	0,088	0,215	0,258

a : * , **, ***, ns : Main effects significant at P< 0,05, P< 0,01, P< 0,001, or not significant, respectively.

blooming and ripening, and the extent of decline was the lowest in Chardonnay regardless of the rootstocks.

Anderson et al. [1] investigated 14 rootstocks combined with 3 scions. They found that rootstocks had significant influence on the levels of N and NO_3 .

In our experiment the following tendencies can be observed. At blooming in five years average on all of the scion varieties the highest nitrogen value was measured in the leaves of vines that were grafted on the 140Ru rootstock and in the case of the three scion varieties (except for the Chardonnay) the 125AA rootstock had the lowest values. Among the scion varieties the Italian Riesling showed the widest range of N concentration by rootstocks, and at ripening in this variety the above mentioned two rootstocks showed the most extreme values too.

Probably the reason for the different results was in the soil's physical properties and chemical characters, which affected the nutritional status of the vines' leaves. According to Bogoni et.al. [3] nitrogen nutritional status was related to soil temperature, penetrometer resistance and to the vegetative growth of the vines.

Phosphorus

P levels of the leaves ranged in a wide interval - from the very low to the very high. There was no statistically perceptible difference among scions regarding the phosphorous content of the leaves in the examined period. Kocsis et al. [14] observed large differences in P levels and the scion appeared to have the greatest effect on P level. Considering the examined years separately we found the effect of scion to the phosphorus content at ripening to be perceptible in three of the five years.

According to Grant and Matthews [10] the rootstocks differ in their ability to utilize the P from the soil, to transport it from the root to the cane and in the way they effect the scion's utilization of P. Furthermore vines on the different rootstocks partitioned different amounts of P into petioles under sufficient but not under P deficient conditions.

If the scion is taken as repetition by ANOVA we get significant differences between rootstocks (Figure 1). In this case at blooming the phosphorus content of the leaves on rootstocks with Berlandieri x Riparia genetic background (5C, 5BB, 125AA) were lower than other examined rootstocks. This result partly corresponds with opinion Candolfi-Vasconcelos et al. [5], they ranked 5C among the least efficient stocks in P uptake. In our study the 125AA rootstock showed significantly the lowest level of phosphorus at blooming.

The relative decrease of K and P from blooming to ripening in the petioles and leaf blades is a good indicator of these two nutrient's status [13].

Examining the extent of P alteration in scion varieties from blooming to ripening in five years average, the results are

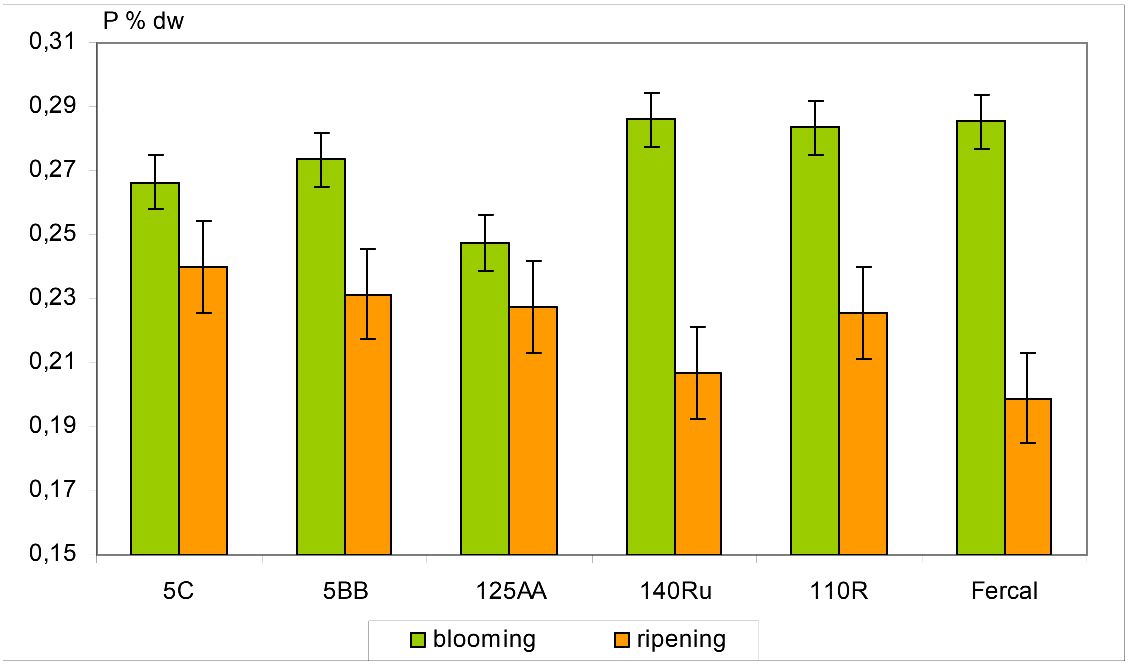

Figure 1. Phosphorus content in the leaf blades by rootstocks

1. ábra. A levéllemez foszfor tartalma, alanyonként

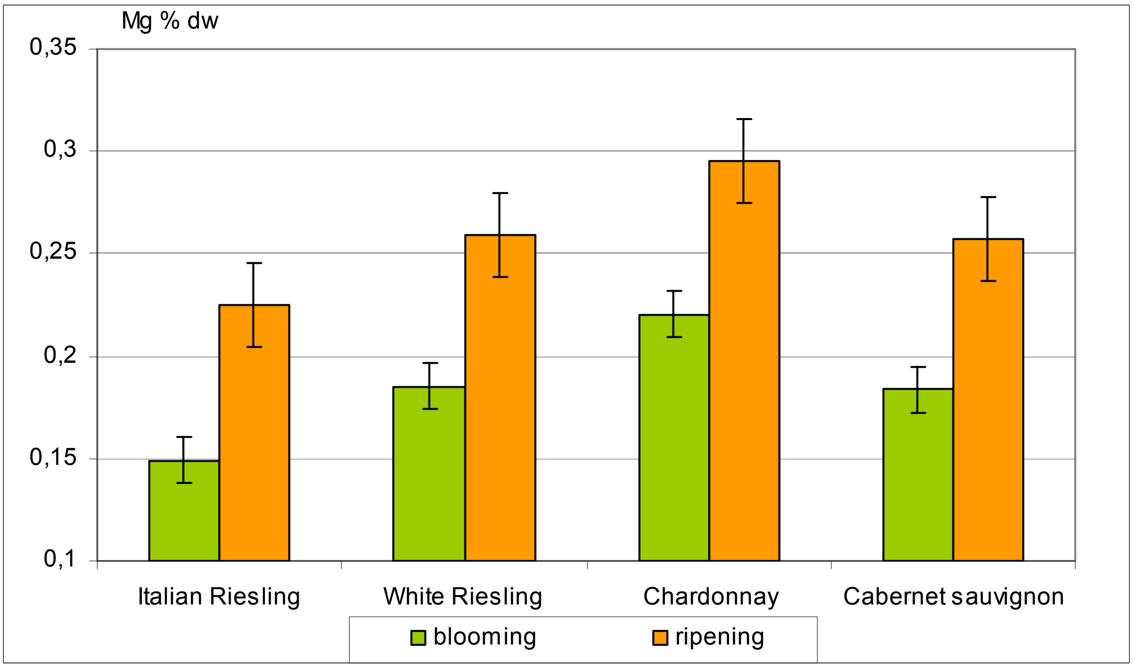

Figure 2. Magnesium content in the leaves by scions
2. ábra. A levelek magnézium tartalma nemes fajtánként

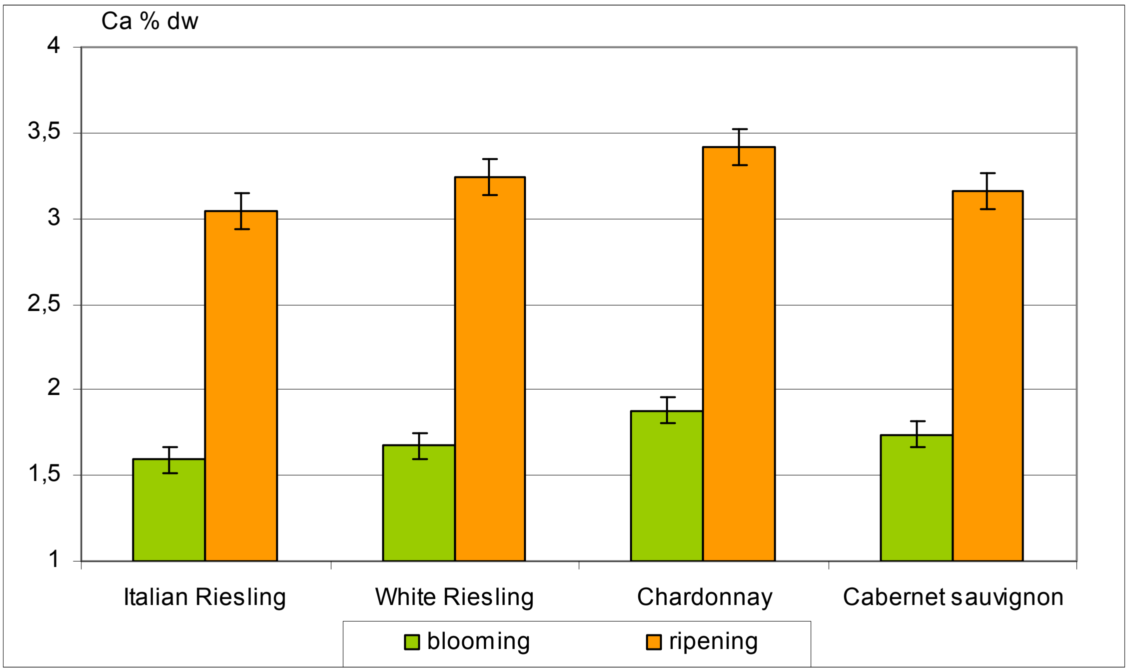

Figure 3. Calcium content in the leaves by scions
3. ábra. A levelek kalcium tartalma nemes fajtánként

the following: In leaves of Italian Riesling and Cabernet sauvignon the phosphorus decrease is significantly lower on the 5C rootstock than on Fercal.

In White Riesling and Chardonnay the extent of phosphorus decrease in rootstocks with Berlandieri x Riparia genetic background is significantly lower than in 140Ru. So by the time of ripening the sequence of the rootstocks has changed regarding the phosphorus content of the leaves. Considering the average of scion varieties the P content of the leaves were lower at ripening on the 140Ru and Fercal rootstocks than on the rootstocks with Berlandieri x Riparia genetic background, first of all the 5C.

Potassium

K content of leaves - similarly to P - ranged in a wide interval.

Potassium content of the leaves show significant differences only at blooming by scions, if the years are considered as repetition (Table 4). It was known, that potassium content of the leaves was determined by scion [6].

The values of Italian Riesling were significantly higher than the Chardonnay's and Cabernet sauvignon's. Failla et al. [7] found that Cabernet sauvignon had lower leaf K content than Chardonnay, however our results did not support this. Potassium content decrease from blooming to ripening was the lowest on Chardonnay and the highest on Italian Riesling. Examining the scion varieties separately, we found a high vintage effect and rootstock effect in White Riesling and Cabernet sauvignon varieties at blooming, and in White Riesling and Chardonnay at ripening. White Riesling shows the lowest values on the 5C rootstock in both examined period.

As Wolpert et.al. [21] describes, we also found that at blooming Cabernet sauvignon and Chardonnay in 5BB rootstock, besides Cabernet sauvignon in 110R rootstock had the lowest K content. At ripening K concentration in the leaves of Chardonnay and White Riesling in 110R and 140Ru were the highest. According to Avenant et al. [2] the reason for the different potassium accumulation rate of rootstocks was in their genetic origin.

Results of Wolpert et al. [21] support, that levels of K concentration might be more broadly classified according to genetic origin of the rootstock. In their study regardless of scion the rootstocks with Vitis berlandieri genetic backgrounds consistently showed negative deviations in petiole K concentration at blooming with respect to the site means, but these differences not exist at ripening. Our conclusion – though statistically not proven – is that K content alteration as opposed to the tendency of P alteration from blooming to ripening was higher in Berlandieri x Riparia originated rootstocks than in other examined rootstocks. Total K levels generally declined significantly between blooming and ripening for all varieties, although the amount and pattern of decline differed among rootstock [21]. A number of authors found that rootstocks had effect on K content of the leaves [1, 4, 8, 14, 16, 21]. Probably the main reasons for the different results were in rootstock-scion interaction, in different soil type and climate characteristics, besides some of the authors investigated petioles not leaf blades, as we did. Leaf lamina K concentrations were much lower than those of petioles. The ranges between the high and low values were much narrower in blades, but trends were consistent with petiole samples [21].

Calcium and magnesium

Ca levels at blooming were in low or optimum range, and by the time of ripening these levels increased sometimes to high range. Mg levels of leaves were in very low - low and optimum range.

Both at blooming and at ripening there were significant differences of calcium and magnesium content of leaves among rootstock and scion varieties too. Rootstock effect on the content of these elements is suggested by some authors, like Fardossi et. al. [8], Kocsis et.al. [14].

According to Sarič [18] magnesium content of leaves was determined more by scion than rootstock – in contrast with Ca, where a reversed sequence can be found. On the other hand according to the ion transport research of Miklós [15] the Ca concentration of leaves is determined decisively by the scion's ability of Ca accumulation.

Calcium and magnesium content of the leaves was significantly higher in Chardonnay at blooming and at ripening too. The lowest calcium and magnesium content were represented by the scion Italian Riesling (Figure 2-3).

Ca content of the leaves was the lowest in the 140Ru stocks, and highest in the 125AA ones. Our field experiment reflects the findings of Miklós [15] regarding the K and Ca ion transport, both in the rootstocks and in the scions. According to her the leaves of the lime tolerant varieties have a high Ca content even in control conditions, and as a result of Ca treatment it has risen considerably. While the sensitive varieties accumulated lesser Ca in their leaves, she considers these varieties exclusives. These varieties are probably the result of the cell wall's different Ca adherence ability. However the leaves and the roots of the sensitive varieties contained more K. This K-Ca antagonism can be observed in our experiment, in the results of the Chardonnay and Italian Riesling or when comparing results of the Berlandieri x Riparia rootstocks with the Berlandieri x Rupestris

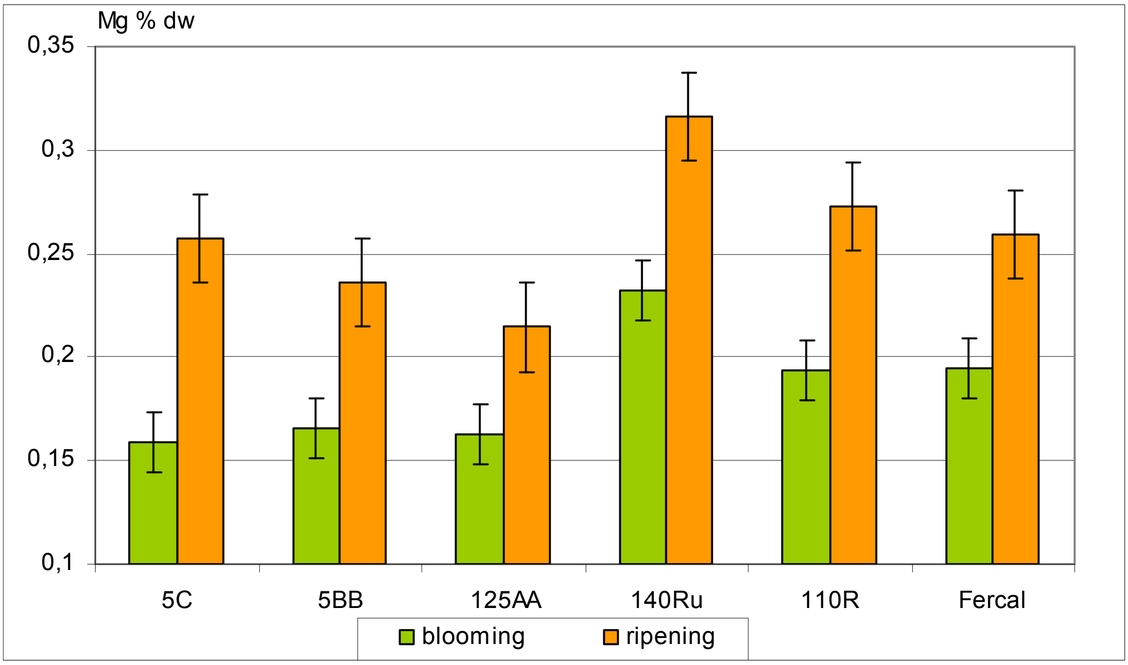

Figure 4. Magnesium content in the leaves by rootstocks
4. ábra. A levelek magnézium tartalma alanyfajtánként

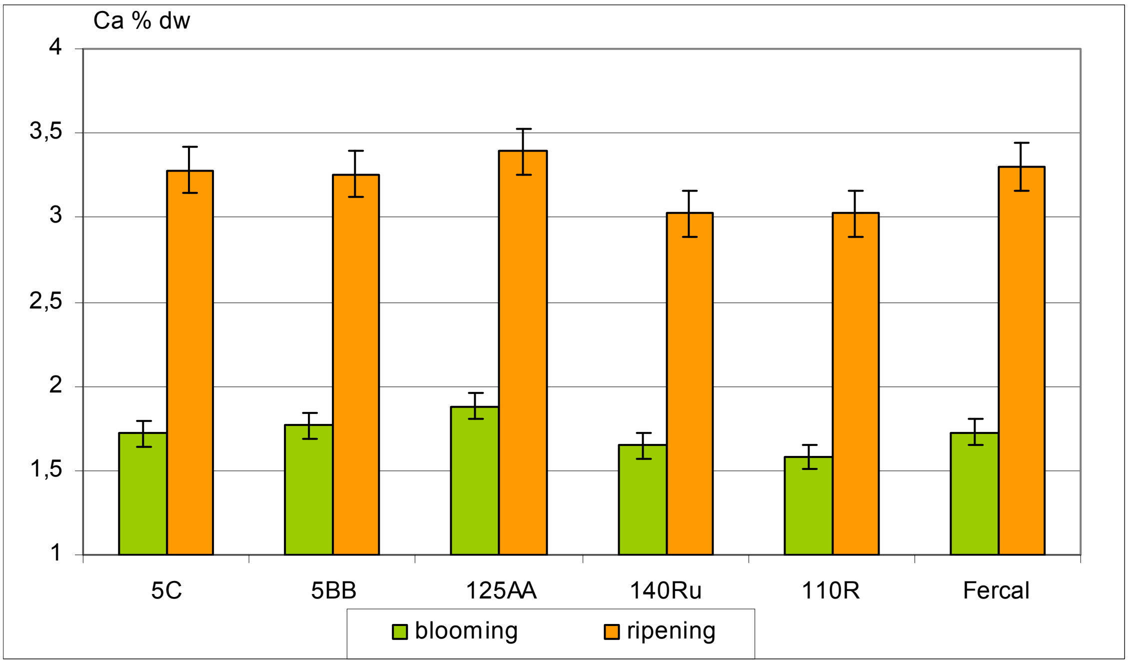

Figure 5. Calcium content in the leaves by rootstocks
5. ábra. A levelek kalcium tartalma alanyfajtánként

rootstocks.

While the Ca and Mg uptake of the scion showed similar tendency, till the uptake of this two elements by rootstock varieties was antagonistic (Figure 4-5). At blooming, besides the 140Ru, the 110R and the Fercal had significantly higher magnesium content in leaves than rootstocks with Berlandieri x Riparia background. At ripening the 140Ru showed the highest value. We do not agree with the conclusion that the 5C rootstock ranked among the least efficient stocks in Mg uptake [5]. In our study at ripening 5C showed as high values as Fercal. But at ripening magnesium content of 125AA was significantly lower than the values of 140Ru, 110R and Fercal.

Macronutrient ratios

According to the classics of plant analysis, concentration shows the quantitative conditions in nutrition, whereas ratio shows the qualitative side. One of the positive features of plant analysis is that it can show interactions that take place during nutrient absorption [11].

Besides the nutrient level of leaf blade, we examined the quantity of macroelements as well, compared with one another. Considering the average of four scion varieties (taking the yearly average values as a basis), in every year we determined the following ratios: N/P, N/K, N/Ca, K/Ca, K/Mg, P/Mg, placing the rootstock effect at the centre of our research.

The N/K ratio falls in the optimum range except for the year 2003. In this year, which was a draughty one, we got especially high values; as well this is the year when the differences among the rootstocks are the highest. In this year the ratio is high in the 5C, 5BB and 140Ru rootstocks, as their N dry mass percentage is high, compared to other rootstocks. In the 5BB rootstock, in other years as well, there are higher N/K ratios compared to other rootstocks, while the 125 AA has the lowest rates. The values of 125AA ranged in a narrow interval during the years examined.

The N/P ratio shows especially high values in 2004, when the rootstock's indexes range in the widest scale as well. The high ratios were caused mainly by the hindered phosphorus absorption. Among the high values of 2004, the 5C has the most moderate ones; considering the years separately this rootstock's indexes show the narrowest ranges.

In the examined period year by year – except for the most extreme year – the N/K and N/P ratios show a growing tendency.

The K/Ca ratio is low in 2003 (especially in the 125 AA), but it is high in 2005 (especially in the 140Ru). This ratio is the highest in 2004 and 2005 - with the reduction of the K values - in the 140Ru and 110R rootstocks. The other extreme is the 5BB, this can be the result of its unfavourable K utilization.

Considering the N/Ca ratios, in every year a positive deviation of the 140Ru and 110R rootstocks can be observed, the reason for this is a lower Ca value resulting from these rootstocks' longer vegetation period. The 125AA shows the lowest ratios, as well as with the N/K ratio.

The K/Mg ratio is not low in any of the cases. According to Avenant et al. [2] the ability of K absorption and accumulation shows a negative correlation with the ability of Mg absorption – this is indicated in the ratios showing nutrient harmony. In our experiment we got extreme high values in 2001, 2002 and 2005 for the rootstocks with Berlandieri x Riparia genetic background, especially for the 125AA. The ratios, regarding the years, show great extremities of 125AA. In 2001, 2002 and 2005 the differences among the rootstocks are higher than the dispersion of the indexes among the years. The K/Mg ratio in every year is the lowest in the 140Ru rootstock.

The P/Mg ratio was the lowest in 2004, when the phosphorus values were very low in every rootstock. Insufficient P supply appears to restrict Mg transport in the xylem, which can lead to symptoms of Mg deficiency [19].

The P/Mg ratio is higher in the Berlandieri x Riparia background rootstocks compared with the others, however these rootstocks show a considerable divergence regarding the years. The lowest P/Mg ratio was on the 140Ru, except for the year 2005.

The greatest difference among rootstocks can be found in those years of the five examined, when the values show positive extremities (N/K in 2003, N/P in 2004, N/Ca in 2005).

While the years with negative extreme values show the smallest difference among rootstocks (P/Mg and K/Ca ratios in 2003). This might be in connection with the fact that the nutrient absorption features of the rootstocks were showed most in extreme vintages and by limited nutrient absorption possibilities. In sustainable agriculture the appropriate choice of rootstock-scion combination is a good means to control the absorption of macroelements, the harvest results and the adaptation to the location.

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