

1998 U. P. HEDRICK AWARD PAPER

## Concentrations of Amino Nitrogen and Soluble Carbohydrates in Bleeding Sap Collected at Bud Break of 'Cabernet Franc' and 'White Riesling' Grapevines Growing on Four Clonal Rootstocks

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### Abstract

Concentrations of amino nitrogen and soluble carbohydrates were measured in bleeding sap collected at bud break from 'White Riesling' clone Niederhausen 378 and 'Cabernet Franc' grapevines growing on either 3309C, 101-14Mgt, SO4 or 5BB rootstocks at Kingsville, OH. Amino nitrogen concentration was higher in sap collected from 'White Riesling' compared to the more vigorous 'Cabernet Franc.' The concentration of soluble carbohydrates in bleeding sap was highest on 'Cabernet Franc'/SO4 vines. Differences in xylem solutes could not be related to cropping in the previous year or to scion effects on vine vigor in the current year. Rootstock did not influence vine vigor in the year of this study. Shoots on 'White Riesling' vines had less leaf area at bloom, and were more fruitful due to the presence of clusters at more basal nodes on the shoot compared to 'Cabernet Franc.'

### Introduction

The primary limitations to production of *vinifera* wine grapes in the north eastern continental United States are phylloxera and winter injury. The limitations imposed by phylloxera have been overcome by grafting *vinifera* scions onto resistant rootstocks. North American species including *V. riparia*, *V. rupestris* and *V. berlandieri* were hybridized in Europe to provide a source of material for rootstocks that were resistant to phylloxera. The genetic material used for either rootstock or scion can influence the winter hardiness of buds on the scion (4) and the uptake of various ions including potassium (3, 10) and chloride (2). Grapevine rootstocks have also been shown to differ in the distribution of roots in the soil (7, 9), influence the partitioning of dry matter to the trunk, and the concentration of nitrogen in the root system and fruit (12). Differences in the partitioning of dry matter to the roots, the distribution of roots in the soil, and the efficiency of mineral uptake by roots will influence the vigor of the vine

and its tolerance of varying soil and environmental stresses.

The root system of grapevines is the major storage site for carbohydrates. Starch in the roots is hydrolyzed to glucose in late winter and early spring (1) and delivered to the developing shoots via the xylem. During the same period nitrogen that was stored in roots as arginine (8) is presumably metabolized to glutamine, which is the predominant form of nitrogen in the bleeding sap of grapevines at bud break (1). Concentrations of soluble carbohydrates and amino nitrogen in the bleeding sap of grapevines at bud break were reduced by conditions in the previous year including shade (6) and heavy crop loads (McArtney and Ferree, unpubl.). While differences in the uptake of various ions have been documented for different grapevine rootstocks, the effects of rootstocks on the remobilization of stored nitrogen and carbohydrates are unknown.

We measured the concentration of soluble carbohydrates and amino nitrogen pre-

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Salaries and research support provided by state and federal funds appropriated to the Ohio Agricultural Research and Development Center, The Ohio State University, Journal Article No.39-98.

sent in bleeding sap of 'White Riesling' and 'Cabernet Franc' grapevines growing on four different clonal rootstocks to see if there was parallel variation between the concentration of these solutes in the sap and the vine vigor or fruitfulness.

### Materials and Methods

Bleeding sap was collected at bud break in 1997 from 'Cabernet Franc' and 'White Riesling' clone Niederhausen 378 grapevines growing on the following four rootstocks: 3309C, 101-14 Mgt., SO4 and 5BB at the OARDC Grape Research Branch, Kingsville, OH. Two canes on each vine were cut at 0830 on May 21, and the sap was collected in 15 ml test tubes through latex tubing attached over the cut end. The origin and viticultural traits of the four rootstocks used in this study, as summarized by Ferree et al., (4) are described in Table 1. The vines were part of a study planted in 1986 (4). The four rootstocks selected for this study were chosen from the 9 rootstocks used in the original experiment, because scion varieties grown on them produced a range of vigor, as determined by cumulative pruning weights over a five year period. More importantly, there was an interaction between these four clonal rootstocks and the two scion cultivars in cumulative pruning weights and vine yields (4). Vines were spaced at 1.8 x 2.7 m, trained as low bilateral cordons with multiple trunks, and pruned annually to 35-40 live buds. The treatments were arranged, and data analyzed, in six replicates of a split plot design with scion variety as the main plot and rootstock as the sub plot.

Bleeding sap was stored at  $-20^{\circ}\text{C}$  until subsequent analyses for amino nitrogen and soluble carbohydrates were conducted using methods described previously (6). Vine yields and pruning weights were recorded in 1996 and 1997, and from these data crop load was calculated as the yield per vine divided by the weight of prunings in the previous winter. Shoot length and leaf width were measured for five sample shoots on each vine at bloom in 1997, and leaf area was estimated from

a calibration curve of area versus width obtained from a sample of more than 200 leaves of each cultivar. The number of clusters and their position on each sample shoot was also recorded at bloom in 1997.

### Results

Rootstock had a significant effect on the concentration of soluble carbohydrates in bleeding sap, but did not affect the concentration of amino nitrogen (Table 2). The scion, on the other hand, significantly influenced the amino nitrogen concentration of bleeding sap, but was without effect on the concentration of soluble carbohydrates (Table 2). The concentration of amino nitrogen was 1.8 times higher in bleeding sap collected from 'White Riesling' compared to 'Cabernet Franc' grapevines (Table 2). There was a significant interaction between rootstock and scion cultivar for the amino nitrogen concentration in bleeding sap. 'White Riesling' vines grown on 5BB had the highest concentration of amino nitrogen ( $279\mu\text{g}\cdot\text{ml}^{-1}$ ), but 'Cabernet Franc' vines grown on the same rootstock had the lowest concentration of amino nitrogen ( $97\mu\text{g}\cdot\text{ml}^{-1}$ ).

Glucose was the major soluble carbohydrate in all combinations of cultivar and rootstock, accounting for between 46-78 percent of the total soluble carbohydrates found in bleeding sap. The concentration of total soluble carbohydrates in bleeding sap ranged from  $39\mu\text{M}$  to  $177\mu\text{M}$  depending on rootstock and scion combination, and this variation was due, in large part, to differences in the concentration of glucose. There was a significant main effect of the clonal rootstock on glucose concentration in bleeding sap. Vines grown on SO4 had higher concentrations of glucose compared with those grown on other rootstocks. Bleeding sap from 'White Riesling' grown on 3309C and 5BB had twice the concentration of glucose compared to 'Cabernet Franc' growing on the same two rootstocks, but when these cultivars were grown on SO4 the concentration was higher in sap from 'Cabernet Franc' compared to 'White Riesling.'

**Table 1. Description and characteristics of four clonal rootstocks used in this study.<sup>1</sup>**

Rootstock	Cross/Originator	Relative vigor*	Soil adaptability			Resistance to			Tolerance lime %
			wet	clay	dry	phyllorhizomatous	drought		
3309C	<i>V. riparia tomentosa</i> x <i>V. rupestris</i> / Cutwork (1881)	2	3	2	2	4	1	2	11
101-14Mgt	<i>V. riparia</i> x <i>V. rupestris</i> / Millardet (1882)	2	3	2	1	4	4	1	9
SO4	<i>V. berlandieri</i> x <i>V. riparia</i> No. 4/Teleki (1886)	2	3	2	1	4	4	3	17
5BB	<i>V. berlandieri</i> seedling/ Teleki (1886)	2	3	2	1	4	3	1	20

<sup>1</sup>taken from Ferree et al. (1996).

\*Vigor: 1 low to 4 = high; Soil adaptability: 1 = poor to 4 = good; Resistance: 1 = very susceptible to 5 = very resistant.

In the year prior to collection of bleeding sap 'Cabernet Franc' vines produced more fruit and more wood was removed at pruning compared to 'White Riesling' vines (Table 3). The rootstocks 3309C and 101-14Mgt were less vigorous than SO4 and 5BB, as determined by the main effects of rootstock on the weight of wood removed at pruning (Table 3). Crop load in the previous year, expressed as the weight of fruit in 1996 per weight of prunings removed after the 1995 growing season, was lower for vines grown on 5BB compared to vines on 3309C, 101-14Mgt, or SO4. There was no main effect of rootstock on yield per vine in the previous

year, but there was a significant interaction between rootstock and scion for yield. The yield per vine for 'White Riesling' grown on 5BB and 3309C was approx. 50 percent compared to vines of the same cultivar grown on 101-14Mgt and SO4. Highest yields from 'Cabernet Franc' were produced by vines on 3309C.

There were no effects of rootstock or scion on vine yield or pruning weight in 1997 (Table 4). Shoots on 'White Riesling' vines were more fruitful compared to 'Cabernet Franc' (Table 4) due to the production of clusters at more basal nodes on the shoot (Figure 1).

**Table 2. Concentration of amino nitrogen and soluble carbohydrates in bleeding sap collected at bud break of 'White Riesling' and 'Cabernet Franc' grapevines growing on four different rootstocks.**

Cultivar	Rootstock	Amino nitrogen ( $\mu\text{g}\cdot\text{ml}^{-1}$ )	Soluble carbohydrates ( $\mu\text{M}$ )				
			Fructose	Glucose	myo-inositol	Sucrose	Total
'White Riesling'	3309C	169	15	55	14	11	94
	101-14Mgt	184	8	42	7	11	67
	SO4	196	7	60	6	11	83
	5BB	279	10	50	8	11	79
Cabernet Franc	3309C	115	6	18	9	7	39
	101-14Mgt	118	6	47	9	11	72
	SO4	116	16	138	13	10	177
	5BB	97	5	23	9	13	49
Significance							
Cultivar		NS	NS	NS	NS	NS	
Rootstock		NS	NS	*	NS	*	
Interaction		*	*	*	NS	NS	

NS,\* and \*\*\* indicate not significant and significant at  $P < 0.05$  and  $0.001$  respectively.

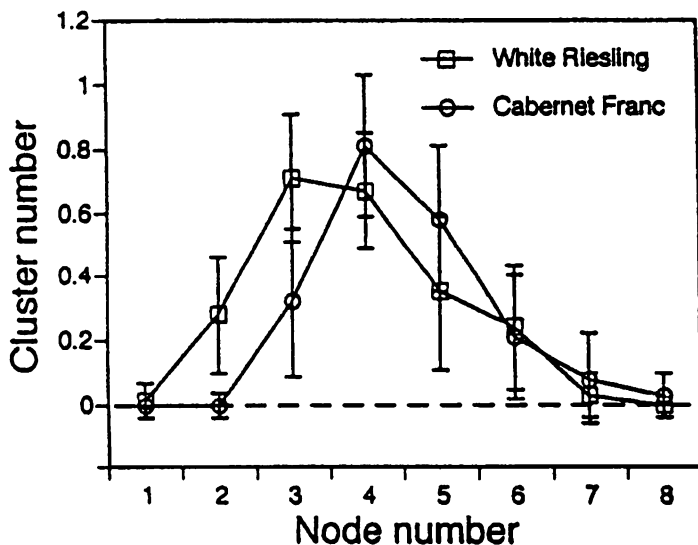


Figure 1. Cluster number at each node on shoots of 'White Riesling' and 'Cabernet Franc' grapevines. Node 1 is at the base of the shoot. Data are the main effect means of five sample shoots per vine.

### Discussion

In the present study we measured differences in the concentration of amino nitrogen and soluble carbohydrates in bleeding sap at bud break from 'Cabernet Franc' and 'White Riesling' grown on

four rootstocks (Table 2). Sap collected from 'White Riesling' contained higher concentrations of amino nitrogen compared to sap collected from 'Cabernet Franc.' There was an interaction between rootstock and scion variety on the amino

Table 3. Vine yields, pruning weights, and crop load of 'White Riesling' and 'Cabernet Franc' growing on four clonal rootstocks in the year prior to sap collection (1996).

Cultivar	Rootstock	Yield (kg. vine <sup>-1</sup> )	Crop load <sup>2</sup>	Pruning weight (kg. vine <sup>-1</sup> )
'White Riesling'	3309C	2.6	5.2	0.6
	101-14Mgt	4.3	5.7	0.5
	SO4	4.9	5.2	1.0
	5BB	1.5	1.5	1.0
Cabernet Franc	3309C	5.7	5.5	1.2
	101-14Mgt	3.5	4.3	1.1
	SO4	4.9	3.5	1.4
	5BB	4.3	2.2	1.7
Significance				
Cultivar		*	NS	***
Rootstock		NS	*	**
Interaction		*	NS	NS

NS, \*, \*\* and \*\*\* indicate not significant and significant at P < 0.05, 0.01 and 0.001 respectively.

<sup>2</sup>Crop Load = 1996 yield + 1995 pruning weight.

**Table 4. Vegetative and fruiting characteristics of 'White Riesling' and 'Cabernet Franc' grapevines growing on four clonal rootstocks in 1996 and 1997.**

	Yield (kg./vine <sup>-1</sup> )	Shoot length at bloom (cm)	Leaf area per shoot at bloom (cm <sup>2</sup> )	Pruning weight (kg./vine <sup>-1</sup> )	Fruitfulness (clusters./shoot <sup>-1</sup> )
Scion cultivar					
'White Riesling'	4.9	41.8	463.7	0.3	2.3
'Cabernet Franc'	5.9	39.5	530.9	0.4	2.0
Rootstock					
3309C	4.9	37.5	464.3	0.3	2.1
101-14Mgt	4.8	42.0	496.5	0.3	2.1
SO4	5.9	41.6	526.4	0.4	2.3
5BB	6.1	41.4	502.0	0.4	2.2
Significance <sup>1</sup>					
Cultivar	NS	NS	*	NS	*
Rootstock	NS	NS	NS	NS	NS

<sup>1</sup>There were no interactions between rootstock and scion cultivar. NS and \* indicate not significant and significant at  $P < 0.05$  respectively.

nitrogen concentration in bleeding sap, due to the high amino nitrogen concentrations in sap from 'White Riesling'/5BB vines compared to 'Cabernet Franc'/5BB. The concentrations of both glucose and total soluble carbohydrates were higher in sap collected from vines growing on SO4 compared to 3309C, 101-14Mgt or 5BB. The effect of rootstock on soluble carbohydrates, and scion cultivar on amino nitrogen, may reflect the site(s) of storage of amino nitrogen and soluble carbohydrates in the vine. The major site of carbohydrate storage in grapevines is the root tissues, and it would be logical to find significant effects of rootstock on the concentration of soluble carbohydrates in the bleeding sap at bud break. For nitrogen however, the major sites of storage are in the wood and bark of the roots and the trunk, so it would be logical to observe an effect of the scion cultivar on amino nitrogen concentration in bleeding sap if nitrogen reserves are being remobilized from trunk tissues in the spring.

The concentration of amino nitrogen was significantly higher in sap collected from 'White Riesling' compared to 'Cabernet Franc,' yet 'White Riesling' is the less vigorous of these two cultivars, as measured by the pruning weights per vine over a five year period (4) and the

leaf area per shoot at bloom in 1997 (Table 4). Since we measured a 2.8-fold difference in the concentration of amino nitrogen in sap across the range of cultivar-rootstock combinations, but were not able to relate these differences to any differences in vine vigor, we propose that vegetative development was not limited by the supply of nitrogen in this study. The concentration of amino nitrogen in bleeding sap at bud break can be reduced by shading (6) or heavy cropping (McArtney and Ferree, unpubl.) in the previous year. The effects of scion cultivar on amino nitrogen may be related to either shading within the canopy or cropping history, since 'Cabernet Franc' vines were more vigorous and produced more fruit in 1996 compared to 'White Riesling' vines and had lower concentrations of amino nitrogen in bleeding sap in 1997. These data highlight the importance of standardizing cropping and other cultural variables in studies of this nature.

Total soluble carbohydrates were significantly higher in vines growing on SO4 compared to vines on 3309C, 101-14Mgt or 5BB. This effect was due to higher concentrations of glucose and fructose in sap collected from 'Cabernet Franc' vines growing on SO4. We hypothesize that a higher proportion of current assimilate

was partitioned to the roots for this rootstock/scion combination. Soluble carbohydrates in the bleeding sap can be reduced by shading (6) or heavy cropping (McArtney and Ferree, unpubl.) in the previous year. Vines on SO4 produced the heaviest crops in 1996 (Table 3) but also had the highest concentration of total soluble carbohydrates in bleeding sap collected in spring of 1997, suggesting that the high levels of carbohydrates might be a true rootstock effect and not a response to a carry-over effect of cropping.

Even though the four rootstocks used in this study were given the same vigor rank (Table 1), they did show differences in vigor, measured as the cumulative weight of wood removed during winter pruning over a five year period (4). Vines growing on 3309C or 101-14Mgt were less vigorous compared to vines growing on SO4 or 5BB. We measured differences in the concentration of amino nitrogen and soluble carbohydrates in bleeding sap collected at bud break that were related to either the scion or rootstock respectively. However these differences were not related to a vigor ranking based on previous data for these rootstocks. In other studies we have found that the concentration of these solutes in the bleeding sap can vary with the light environment and crop load in the previous year. While there were differences in cropping in the previous year for the different combinations of rootstock and scion, all the vines in this study had carried relatively light crops of fruit since 1994, when they had been severely damaged by winter injury.

Differences in grapevine vigor due to rootstock or scion could not be explained by differences in the concentration of soluble carbohydrates or amino nitrogen in bleeding sap. Given these results, we propose that the basis for control of scion vigor by a rootstock may be hormonal rather than nutritional. In support of this, recent studies with apple showed that invigorating rootstocks had higher cytokinin contents and faster rates of auxin transport compared to dwarfing rootstocks (5).

## Literature Cited

1. Andersen, P. C. and B. V. Brodbeck. 1991. Influence of fertilization on xylem fluid chemistry of *Vitis rotundifolia* Noble and *Vitis* hybrid Suwanee. *Am. J. Enol. Vitic.* 42:245-251.
2. Downton, W. J. S. 1977. Chloride accumulation in different species of grapevine. *Scientia Hort.* 7:249-253.
3. Erdei, L., E. Miklos and J. Eifert. 1985. Differences in potassium uptake in grapevine varieties: Reasons and perspectives. *Vitis.* 24:174-182.
4. Ferree, D. C., G. A. Cahoon, M. A. Ellis, D. M. Scurlock, and G. R. Johns. 1996. Influence of eight rootstocks on the performance of 'White Riesling' and 'Cabernet Franc' over five years. *Fruit Var. J.* 50(2):124-130.
5. Kamboj, J. S.; P. S. Blake; J. D. Quinlan and A. D. Webster. 1997. Recent advances in studies on the dwarfing mechanism of apple rootstocks. *Acta Hort.* 451:75-82.
6. McArtney, S. J. and D. C. Ferree. 1998. Shading effects on dry matter allocation, remobilization of stored reserves and early season vegetative development of grapevines in the year after treatment. submitted to *J. Am. Soc. Hort. Sc.*
7. Morano, L. and W. M. Kliever. 1994. Root distribution of three grapevine rootstocks grafted to Cabernet Sauvignon grown on an very gravelly clay loam soil in Oakville, California. *Am. J. Enol. Vitic.* 45(3):345-348.
8. Nassar, A. R. and W. M. Kliever. 1966. Free amino acids in various parts of *Vitis vinifera* at different stages of development. *Proc. Am. Soc. Hort. Sci.* 89:281-294.
9. Perry, R. L., S. D. Lyda and H. H. Bowen. 1983. Root distribution of four *Vitis* cultivars. *Plant and Soil.* 71:63-74.
10. RuhI, E. H. 1989. Uptake and distribution of potassium by grapevine rootstocks and its implication for grape juice pH of scion varieties. *Aust. J. Exp. Agric.* 29:707-712.
11. Winkler, A. J. and W. O. Williams. 1945. Starch and sugars of *Vitis vinifera*. *Plant Phys.* 20:412-432.
12. Williams, L. E. and R. J. Smith. 1991. The effect of rootstock on the partitioning of dry weight, nitrogen and potassium, and root distribution of Cabernet Sauvignon grapevines. *Am. J. Enol. Vitic.* 42(2):118-121.