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Influence of Defoliation on Carbohydrate Reserves of Young Grapevines in the Nursery

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Summary

The influence of partial and total defoliation of grafted vines, performed during the period of intensive growth (July, August, September), on the accumulation of carbohydrates in roots, canes and rootstock was studied in *Vitis vinifera* L. ssp. *sativa* cv. 'Riesling', clone 239 grafted on the rootstock 'SO4', clone 31. Total defoliation in July resulted in the lowest percentage yield of grafted vines and the lowest weight of roots. In canes, total defoliation caused the lowest total carbohydrate content (TCC) in September, whereas in roots, the lowest TCC was established in August and September, in particular, owing to the reduced starch content. The most significant difference in the TCC between partial and total defoliation was observed in August.

Key words. grapevine – grafted vine – defoliation – carbohydrates

Introduction

In grafted vines, the root development and healing of the graft union are particulary affected by the water content and by carbohydrates stored in scions and rootstock. The accumulation, transformation and translocation of carbohydrates in individual parts of the grapevine have been described in the literature by various authors (Koblet 1969, 1975; Schaefer 1978, 1986a, b; Koblet and Perret 1990; Koblet et al. 1993; Candolfi-Vasconcelos et al. 1994, 1995). Warmund et al. (1986), Schaefer and Schropp (1987), Schumann and Schaefer (1988), and (Vršič 1996) examined various effects of individual procedures for the cultivation of grafted vines on the level of substances stored in the grafted vines. The effects of defoliation on the accumulation of stored substances were investigated, especially in the case of grapevines at several years of age in a vineyard. It was found that severe defoliation results in a lower mass of one-year wood that carbohydrates are mobilised from plant reserves, and that the vines take up to two years to replace these (Koblet 1985; Koblet and Candolfi-Vasconcelos 1992; Koblet et al. 1993, 1994a, b; Candolfi-Vasconcelos et al. 1995; Duchene et al. 2003). Early severe defoliation has a negative effect on carbohydrate accumulation, starch in particular (Koblet and Candolfi-Vasconcelos 1995a, b; Petgen and Götz 2004; Bennett et al. 2005), and defoliated grape vines are less resistant to cold (Howell et al. 1994) and have a weak growth (Petrie at al. 2003). Defoliation at veraison did not affect cluster number and crop yield per vine (Bavaresco et al. 2008). The aim of our study was to establish at which growth stage of grafted vines in a nursery the defoliation has the most negative effect on quality in relation to vine development and carbohydrate accumulation.

Materials and Methods

The effects of defoliation of grafted vines on the quantity of carbohydrates in the roots, canes and rootstock were studied in grafted vines of *Vitis vinifera* L. cv. 'Riesling', clone 239 Gm grafted on the rootstock 'SO4', clone 31 Opp. The preparation of rootstock and scions, the grafting technique and the technological procedures applied in the nursery were as described by Schropp and Maul (1991) and Vršič (1991). Our study included (1) experiments in the nursery and (2) pot experiments. The experiments in the nursery were based on a randomized complete block design with seven treatments and five replications (each including 10 grafted vines). The pot experiments included the same treatments, but each included only 5 grafted vines. In each experimental period, both experiments included treatments with total defoliation, those with partial defoliation, and a control (with no defoliation). The defoliation was carried out at the time of intensive growth of the grafted vines, i. e., in the second decade of July (15.07), August (15.08) and September (15.09). Since grapevine leaves are relatively symmetrical, for partial defoliation, half the leaf area was removed along the main leaf vein. We measured the surface of the leaf area removed (by means of a scanner in cm^2). We weighed the canes, roots and rootstock [dry weight ($g\ kg^{-1}$), dried at 105 °C] and analysed the content of carbohydrates, proteins and macro- and microelements. The analyses were carried out by applying the methods described by Pánczél and Eifert (1960), Kaserer et al. (1990) and Helrich (1990). Statistical evaluation of data was performed by the SPSS15.0 program with one way analysis of variance (ANOVA). Means were separated by the LSD test. Statistical significance was evaluated at $P \leq 0.05$.

Results

The effect of defoliation on the growth and development of grafted vines

The percentage of grafted vines with well healed and hardened graft unions was lowest when the defoliation was carried out in July. In comparison to defoliation carried out in August, September and the control, it ranged between 28 and 38 % in totally defoliated grafted vines, and was around 12 % in partially defoliated ones. It was established that healing and hardening of the graft union was considerably affected by the time of defoliation and the quantity of leaf area removed. The later the defoliation and the less intensive its application, the higher was the percentage yield of grafted vines. The weight of canes in partially defoliated grafted vines was 7 % to 34 % lower, and in totally defoliated grafted vines, 19 % to 46 % lower, compared to the control (the later the time of defoliation, the smaller the differences were). Significant differences were also established between the totally defoliated grafted vines in July and the partially defoliated ones in September, and the control. In the pot experiment (1994) the weight of canes in the control was similar to the average in the nursery (5.7 g/grafted vine). The weight of the roots in the control and of those in the grafted vines partially defoliated in July was statistically significantly higher than the weight of the roots of those grafted vines totally defoliated in July and August (in the pot experiment, only in the control), and had increased by 18–33 % (P = 0.05). There were no other statistically significant differences (Table 1).

Carbohydrates in grafted vines

In the nursery, in terms of the development of grafted vines, the state of carbohydrates was slightly different. In grafted vines totally defoliated in September, the starch content was lower by almost half compared to the control, and the content of total carbohydrates was lower by a third (P = 0.01). The same trend was also observed in the protein content of canes (Table 2). In the rootstock we observed the lowest content of starch and of total carbohydrates in grafted vines totally defoliated in August and September. In comparison to the control, the starch content was 31–37 % lower, and the content of total carbohydrates was 19–25 % lower (P = 0.01). In the rootstock, the highest accumulation of starch was observed in September, which was evidenced by a reduction in its content by one-third in totally defoliated grafted vines (Table 2). In all treatments the content of starch and total carbohydrates in roots was significantly lower than in the control. In totally defoliated grafted vines, the starch content was 25 % (15.07.) and 42 % (15.08.) lower compared to the control, and in partially defoliated grafted vines by 18 % (15.07) and 35 % (15.09) lower than in the control (P = 0.01). Similar relations were also established for total carbohydrates (Table 2). A significant difference between the two defoliations was observed only in August. In totally defoliated grafted vines, the starch content in roots was 28 % lower and the total carbohydrate content 21 % lower than in partially defoliated grafted vines (P = 0.01).

In the pot experiments, the protein content in canes of totally defoliated grafted vines was 13–17 % lower compared to the control. In partially defoliated grafted vines, there were significant differences only between grafted vines defoliated in September and those in the control. In the canes, the starch percentage in grafted vines in the control at the end of vegetation growth accounted for half the carbohydrates, whereas in grafted vines totally defoliated in August and September for only a third, although total carbohydrate values, on average, were not different, except for the grafted vines totally defoliated in September. In the rootstock, the protein content was higher in grafted vines partially defoliated in August and September, whereas in July there were no significant differences between the two defoliations. Compared to the control, in the roots of totally defoliated grafted vines there was less starch: 7 % less in July and up to 47 % in September. In the roots of partially defoliated grafted vines, the starch percentage was 7–26 % lower. In the pot experiments the percentage of starch among the total carbohydrates in the roots was 10–20 % lower compared to results from the experiments carried out in the nursery. In the roots, the lowest starch and total carbohydrate content was established in all grafted vines partially defoliated in August (Fig. 1).

Table 1. The effect of timing of grafted vine cv. 'Riesling' defoliation in the nursery on the average percentage yield of grafted vines, cane dry weight and root dry weight in the period 1994–1996.

Defoliation	Removed leaves (cm^2 $g.v.^{-1}$)	Grafted vines obtained (%)	Cane dry weight (g $g.v.^{-1}$)	Root dry weight (g $g.v.^{-1}$)
July (P)	235	71.9 b	3.9 ab	9.2 a
July (T)	481	46.1 c	3.3 b	7.2 b
August (P)	433	84.2 a	4.6 ab	8.6 ab
August (T)	926	74.0 b	4.1 ab	7.0 b
September (P)	528	83.8 a	5.5 a	8.8 ab
September (T)	1129	83.3 a	4.8 ab	8.5 ab
Control	0	84.5 a	5.9 a	10.4 a

g.v. = grafted vine; P = partial defoliation; T = total defoliation
Means within each column with the same letter are not significantly different at LSD test (P < 0.05).

Table 2. The effect of timing of grafted vine cv. 'Riesling' defoliation in the nursery (1996) on protein, starch, sugar and total carbohydrate content (TCC) (g kg dry weight^{-1}) in roots, canes and rootstock

Defoliation	Roots				Canes				Rootstock			
	Protein	Starch	Sugar	TCC	Protein	Starch	Sugar	TCC	Protein	Starch	Sugar	TCC
Jul. (P)	69.4	239.7 b	56.7 ab	296.4 b	49.6	51.5 bc	45.1 b	96.6 b	34.9	59.3 a	41.9 ab	101.2 a
Jul. (T)	67.1	218.6 b	56.6 ab	275.2 ab	49.1	57.7 abc	47.1 ab	114.8 ab	31.7	53.9 ab	42.5 ab	96.4 ab
Aug. (P)	70.3	232.9 b	52.2 b	285.1 b	48.5	60.4 ab	53.1 ab	113.5 ab	32.4	53.7 ab	41.7 ab	95.4 ab
Aug. (T)	64.5	168.9 c	57.1 ab	226.0 c	44.3	50.8 bc	53.1 ab	103.9 ab	30.9	43.4c	46.3 ab	89.7 b
Sept. (P)	67.7	181.5 c	60.8 ab	242.3 c	44.8	61.5 ab	46.3 ab	97.8 b	30.6	57.0 ab	40.6 b	97.6 ab
Sept. (T)	73.9	190.4 c	63.3 ab	253.7 bc	43.2	35.3 c	45.2 b	80.5 b	31.0	40.0c	42.6 ab	82.6 b
Control	65.0	293.6 a	64.1 a	357.7 a	50.0	63.9 a	58.3 a	122.2 a	36.1	62.9 a	47.0 a	109.9 a

P = partial defoliation; T = total defoliation
Means within the each column with the same letter are not significantly different at LSD test ($P < 0.05$).

Discussion

The defoliation performed at the time of the most intensive growth of grafted vines (July, August) had the most negative effects. In totally defoliated grafted vines the supply of assimilates was temporarily interrupted. This hampered the differentiation of callus into vascular tissue, which is confirmed by the fact that the lowest portion of well healed and hardened grafts occurred in July. Also the quality of totally defoliated grafted vines was worse, which is evident from the lowest weight of their canes and roots (Table 1). Candolfi-Vasconcelos et al. (1994a, b) also documented a lower weight for roots in vineyard conditions.

A lower accumulation of carbohydrates in one-year wood of the grafted vines can also be expected in grafted vines defoliated in September and August (Table 2). This result is in accordance with the findings of investigations of older vines carried out by Scholefield et al. (1978) and Marangoni et al. (1980). The canes with fewer leaves contained more water and less starch; more severe defoliation resulted in a lower weight of one-year wood, a finding which was also established for vineyard-grown vines (Hügelschäfer et al. 1992, 1994; Koblet et al. 1994a). In our experiments in the nursery, we established the lowest weight of canes in grafted vines totally defoliated in July (Table 1).

The differences in starch and total carbohydrate content were most significant in the roots. More intensive growth of grafted vines begins in mid June. Koblet and Perret (1990) established that, in vines from a vineyard, the flow of assimilates from all the leaves to the growing roots starts at the end of July. In grafted vines this most probably begins in August or even in September, since in August we established the most negative effect of defoliation on the total quantity of carbohydrates in the roots. In July the young vines with partially or totally removed leaves developed young leaves (also on their lateral shoots), and the accumulation of carbohydrates in the roots of these grafted vines was higher in the second half of the vegetative growth period. In the nursery, during individual periods there can be a lack of water, which may result in less intensive accumulation of carbohydrates. This was established by Rühl and Alleweldt (1990) in the stem and roots of vineyard-grown vines. In defoliated grafted vines, the roots are thinner (lower weight). Our results show that the non-defoliated grafted vines had 40–58 % more total carbohydrates in the roots than the

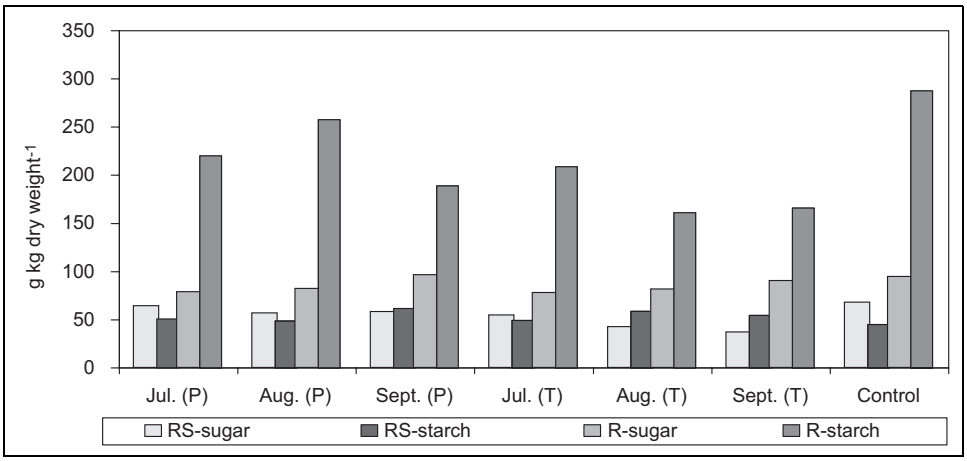


Fig. 1. Soluble sugar and starch content (g kg dry weight^{-1}) in rootstock (RS) and roots (R) in grafted vines cv. 'Riesling' at different times of partial (P) and total (T) defoliation (year 1994; pot experiment)

grafted vines that were totally defoliated in August and September, which was mainly due to the higher starch content. The most considerable difference in the total content of carbohydrates was observed between the grafted vines totally defoliated and partially defoliated in August. The highest content of carbohydrates was established in the roots, followed by the rootstock, and the lowest in the canes. Owing to the lower quantity of stored substances in defoliated grafted vines, in the first year less vigorous growth was observed in these in the vineyard. In regions with a continental climate (at low autumn temperatures), the canes of these grape vines and parts of the rootstock above the plastic sheeting can be affected by frost.

The majority of the stored assimilates that are needed in the subsequent year for successful growth in the vineyard is accumulated in the roots and rootstock. In the second half of the vegetation growth period, the growth of young grafted vines becomes less intensive, and the flow of carbohydrates is directed to the roots and the rootstock of the grafted vine. We established that the reduced leaf area in the second half of July or at the beginning of August has the least negative impact on the quality of grafted vines, as long as the quantity of the leaf removed does not exceed half the total leaf area. If the majority of the leaf area is damaged, the accumulation of assimilates is temporarily interrupted and/or lowered, since many carbohydrates (sugars) are re-translocated from the roots and rootstock to renew the leaf area. This has been established in vines at full maturity by KOBLET (1985) and KOBLET and CANDOLFI-VASCONCELOS (1992). It should be taken into consideration that leaves at an earlier stage of development have a lower net assimilation rate and fewer assimilates available for accumulating reserves, which has also been shown by our results on defoliation performed in August.

FOURNIOUX (2001) reported about the negative effects of defoliation on the apical activity shoots of grapevine cuttings. However, there are no research data about the influence of defoliation on young grafted vines. Drastic leaf area reduction, which can be caused by hail, diseases and too intensive shoot topping, may represent a significant stress. The results of our study show that the intensive defoliation had a negative effect on the quality of young grafted vines in all growth stages. One of the consequences of early defoliation of young grafted vines (at the beginning of their intensive growth in July) was worse healing and incomplete hardening of grafted unions. In the second half of the vegetation growth period (August, September), defoliation caused a significant reduction of carbohydrates reserves. Our study shows that leaf area management in nurseries, which is closely associated with photosynthesis and carbohybrate production, may represent one of the crucial factors of the success in the production of good quality grafted vines. In the future, however, it may also be interesting to investigate the dynamics of anorganic reserve substancies such as minerals.

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