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Quality of Grapevines – Endogenous and Exogenous Factors and Their Differing Influences

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Abstract. Viticulture as part of agricultural cropping systems needs specific growing conditions. In particular grapevines need a specific climate and monitoring due to plant diseases. Currently, production philosophy changed from a high yielding practice to a high quality production, accepting as a consequence also lower yields. Mineral nutrition of grapevines forms the grass-roots level of yield oriented as well as of quality oriented production. Under those circumstances it is necessary to know the nutrient demands of this crop to make the proper decisions for fertilization and quality to be achieved. The mineral nutrients (kg/ha) taken up by medium – heavy crop (75-100 hL must/ha) are as follows: N – 65-75, P – 5-10, K – 65-85. Bunches alone remove: N – 25-30, P – 2-4, and K – 40-50. Figures for total uptake may serve as a general guideline for fertilization. In practice uptake rhythm of the different nutrients is more important, which leads to a reasonable nutrient application. The accumulation of nutrients in berries revealed that specific parts of the organ serve as preferred sinks.

Keywords: grapevine quality, nutrient uptake, N, P, K, uptake rhythm

INTRODUCTION

Thirty to forty years ago the wine industry believed that the quality of the pre-product is of minor importance in the wine making chain, because modern equipment (pressures, centrifuges, flotation systems, membrane apparatus etc.) allows figuring out an appreciable wine quality. More and more the consumer's habits changed: getting in contact with the global wine offer and their various styles, consumer tried to get to the bottom of the differences. Also wine industry began to change and entering a new era of winemaking.

Basic idea during the last ten to fifteen years, which took place in viti-viniculture was that "terroir" will have an ultimate influence on wine quality, i.e. grapevines gather all information from the surroundings (climate, soil, man's manipulations a.s.o) into the grapes, which can be found later after production process (Hoppmann and Schaller, 1999). Terroir has also some pitfalls and hypothesis, which can be hardly proven.

Discussing wine quality, the first step should not the introduction of the term "terroir" with its specific and abstract concepts; in contrast it is necessary to look for the scientific roots, and for traceable finding and results, which may be in accordance to overall scientific standards (Hoppmann and Schaller, 1981a, 1981b, 1999; Schaller, 1995).

MATERIALS AND METHODS

Test sites, soil and plant testing methods as well as statistical procedures are described in Hoppmann and Schaller (1981a,b), Schaller *et al*. (1989) and Schaller *et al*. (1992).

RESULTS AND DISCUSSION

I. Ecosystem and grapevine interactions

Grapevines are parts of natural ecosystems and react upon every change in it. An overview of the most possible interaction is shown in Fig. 1. Grapevines grow in a relatively complex production system as compared to a normal agricultural food plant e.g. wheat. Especially meso- and micro-climate have a stunning effect on growth and formation of quality compounds. The more static factors like soil with its chemical and physical internals and varieties as well as rootstocks may exert a minor influence because their variability is lower.

As can be seen, viticulture production is a complicated web, which can only be resolved by continuous research efforts and a highly interlinked work of different scientific disciplines.

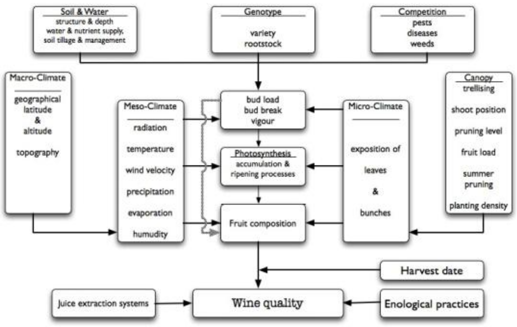

Fig. 1: Possible interactions of grapevines in a viticulture ecosystem (redrawn and adapted according to R. Smart (1991))

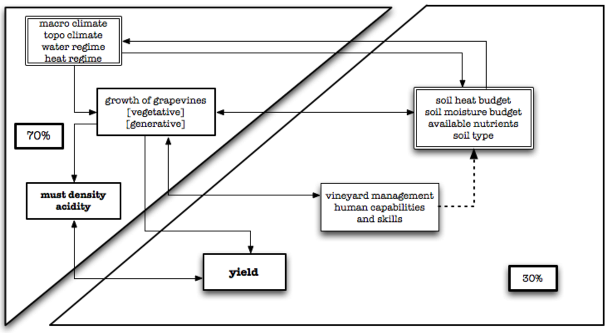

Fig. 2: Flow chart of the climatologic, pedologic and human factors influencing quality and yield of grapevines under cool climate conditions

Influence of agro-meteorological conditions

During a long time trial Hoppmann and Schaller (1981) found out that sugar accumulation in berries and acidity are mainly affected by climatic factors and to a lesser extent by soil properties and managerial characteristics. Figure 2 shows the linkages between these three items.

The climatic complex covers roughly 60-70% of the overall variability, which develops during that 12 years experiment. Only 30% are covered by soil characteristics. These results indicate very well the outstanding importance of weather conditions (macro, meso and micro climate) in viticulture. Nevertheless both parts in that production scheme are linked to each other, because activities of men may exert an influence on meso or micro climate respectively on soil quality.

The composition of the soil, i.e. chemical compounds and physical characteristics, has a marked impact on quality compounds of grapevines (Fig. 3). Calculating a multiple regression with “must density” and “acidity” as dependant variable and soil nutrients as independent ones, it is possible to figure out the most influencing variables, responsible for sugar or acidity accumulation.

Must density (Fig. 3 left) is a function of assimilable phosphorus in the subsoil (+), exchangeable potassium in subsoil (-), and light assimilable potassium in topsoil (+); these three factors determine approx. 33% of the annual variability of must density.

Must acidity (Fig 3, right), on the other hand side, is mainly controlled by two factors. Most important is the assimilable phosphorus content in the subsoil and exchangeable Mg content in the topsoil. Both are negatively correlated with acidity contents in musts and determine approx. 33% of the annual variability (Hoppmann and Schaller, 1999).

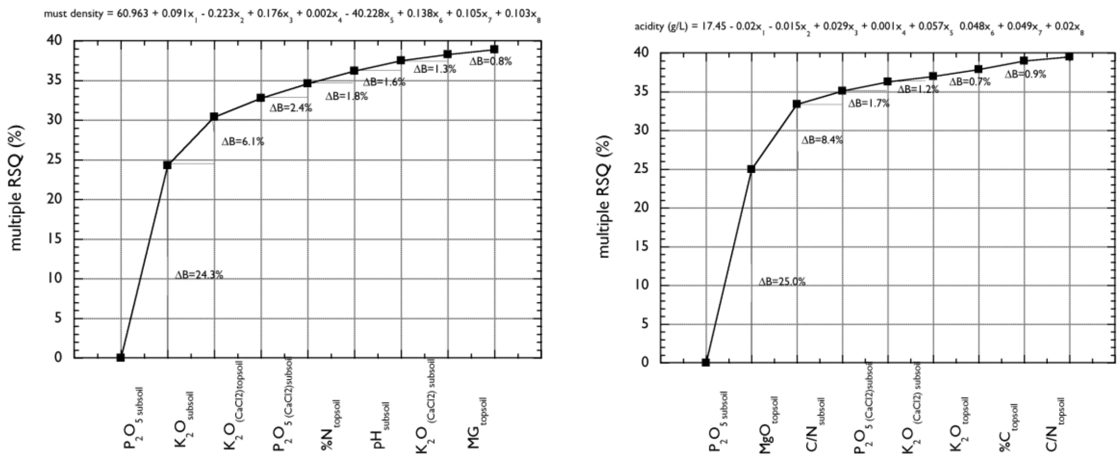

Fig. 3: Soil chemical compounds and their influence on must density (left) and must acidity (right)

These findings allow an assessment of growth and development of grapevines on a macro scale and will give an indication where or not to install a vineyard in a specific site. Those models cannot be transformed to a meso-scale level because other factors are getting more important for the developmental processes of grapevines.

II. Grapevines and their nutrient demands

Productivity of grapevines is dependent on the normal plant production techniques e.g. variety (scion and rootstock), soil cultivation, trellising, pruning (bud load), plant protection a.s.o., as well as the nutrition with different essential elements. The latter will also determine to a great extent yields and quality. A well known fact is that all agricultural plants take up different amounts of nutrient during their growth and development. Height and time course of nutrient uptake are characteristic for the different plant species and determine finally the amount of fertilizing material, which will be needed for a successful viticulture.

Nutrient uptake

The nutrient, which has the most remarkable influence on the grapevines, is **nitrogen**. This element can boost vegetative growth but also influence the formation of generative organs in a quantitative and qualitative way.

A lot of controversies existed about the amounts of nitrogen, which are necessary to save the productivity and the quality of the berries, which are needed as pre-product for winemaking.

Grapevines as perennials have a nutrient uptake pattern, which is different from annual plants. The trunk system including the multi-annual wooden parts serve also as storage organs for nutrients, esp. nitrogen.

The behaviour of N and soluble amino acids in the wooden parts is shown in Fig.4. During the first weeks of development N is depleted until the beginning of blooming. After that, nitrogen is relocated again in trunk and old wood. Soluble amino acids (right graph) increase in annual wood during the phase before bud break and decreases very rapidly when the first flush of young leaves emerges. The highest dynamic of amino acids is found in annual wood and the roots. Strongest depletion occurs during the phase of bloom until veraison. After bloom and berry development total nitrogen as well as soluble amino acids slightly increase in roots and rootstock (Löhnertz and Schaller, 1992; Schaller *et al*. 1989)

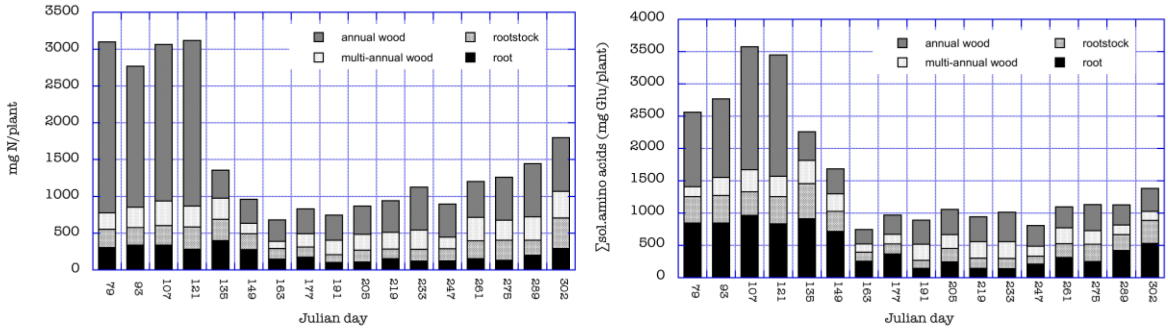

Fig. 4: Total nitrogen (left graph) and soluble amino acids (right graph) in the wooden parts of grapevines during a growing cycle

From these findings it can be reasoned that during the first phase of development after bud break most of the nitrogen, which will be used for the build-up of the first leaves is derived from the wooden parts; after that period external nitrogen should be applied.

The above mentioned findings give only an indication how the plant uses the N-pool, which is build up during the annual growth cycle of grapevines. With this information it is not possible to deduce the amount of fertilizers to be annually applied in vineyards.

The average annual nitrogen load, which has to be applied, needs the information how many kg of N are taken up by vegetative and generative parts of the plant.

Total N uptake of grapevines and its time rate are shown in Fig 5. In the left graph the Total N uptake is shown and in the right parts the time course.

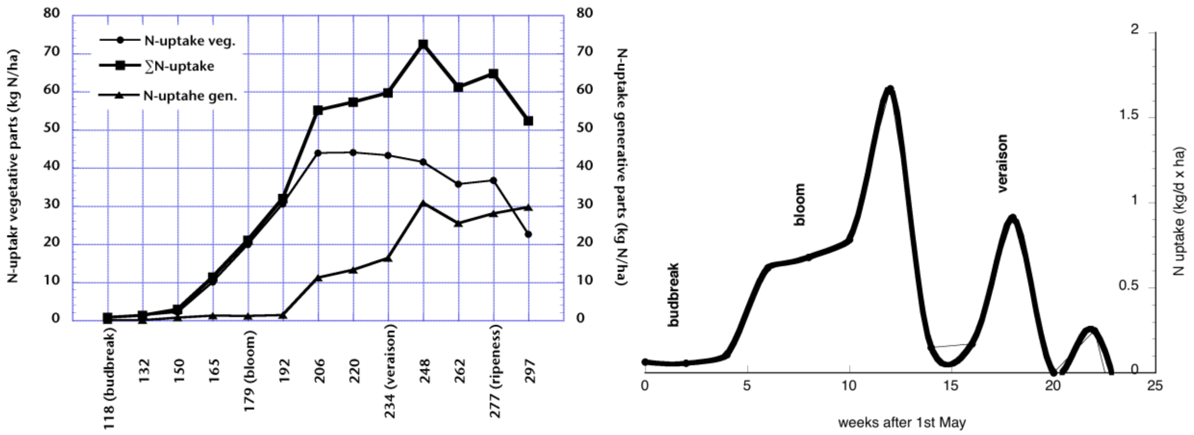

Fig. 5: Total N uptake (left graph) and time rate (right graph) of grapevines during a growing season (Löhnertz & Schaller, 1992)

Results show that maximum total N-uptake is shortly after veraison (Fig.5, left) with an amount of 70-75 kg N/ha. N-storage in vegetative parts is finished two to three weeks after bloom; remarkable N-storage in generative organs starts two weeks after bloom. Maximum N content in bunches is achieved two weeks after veraison with 30 kg N/ha.

The dynamic of N-uptake is demonstrated in Fig 5 (right). A remarkable fact is, that during the first part of the growing season the daily uptake is extremely low, but increases when 5-6 leaves are unfolded and reaches a maximum after bloom with 1,7-2,0 kg N/ha x day for just one week. Then uptake rate declines rapidly and round veraison N-uptake increases again up to 1 kg N /ha x day for 8 to 10 days. It is supposed that during this second peak nitrogen is transferred into ripening berries and may improve overall must quality.

The process of N incorporation in berries is shown in Fig. 6.

It is obvious that nitrogen has highest concentration in the pulp, but declines very rapidly during berry development, especially when water and sugar are accumulated and nitrogen is “diluted”. N concentrations in skin and seeds are more or less unaffected by the ripening process and stay on a constant level (Fig. 6, left).

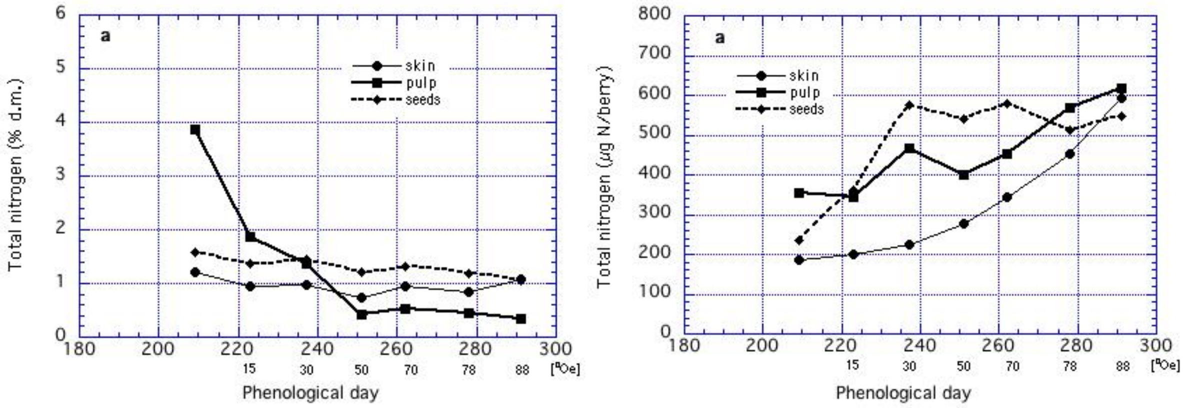

Fig. 6: Time course of nitrogen storage in berries (c.v. Riesling) on dry matter (left) and berry basis (right).

Referred on a berry basis (right graph), N accumulation in seeds is already finished before veraison and it seems that they have a high sink activity. On the other hand side both skin as well as pulp show a similar pattern of N-uptake: with increasing sugar content N deposition in both organs increases (Fig. 6, right).

Grapevines have storage organs (trunk, roots) with which they can save considerable amounts of nitrogen during winter rest (Löhnertz and Schaller 1989). This reservoir is responsible for the build up of new vegetative material after bud break (Schaller and Löhnertz 1990). External addition of fertilizer N is only necessary when the soil cannot fulfil the plant’s demand. The results indicate that fertilization is recommended at or after developmental stage 5-6 leaves unfolded, which should not exceed 40-50 kg N/ha. Sustaining the formation of quality musts, a second N application may be reasonable with 10-15 kg N/ha round veraison (Schaller, 1995).

<u>Phosphorus</u>

Phosphorus is as important as nitrogen. Fig 7 (left) shows that P is taken up in amounts of roughly one tenth of the total nitrogen, i.e. 7- to 8 kg P. Already 70% of total P is taken up two weeks after bloom. That means, during this time of development enough amounts of slightly available P should in the soil solution. Fig. 7 (right) indicates the importance of P-availability during the time after bud break until berry set. P uptake just before and after bloom seems to be critical. Under normal circumstances P is not a limiting factor in viticulture soils; in fact it is a question of its availability. Therefore all cultural techniques and measures should be used to improve its solubility: green manure techniques and intercropping with special di- and monocots should be taken into consideration. Field tests prove that green cover and also green manure improve P-uptake of plants and P-availability.

Uptake and storage in berries during their growth and development is shown in Fig. 8. The concentration of P in berries is demonstrated in left graph. Similar to the time course of nitrogen highest concentrations are found at the beginning in the pulp. It decreases very rapidly whereas concentrations in seeds and skins stay quite constant. Highest values are finally found in seeds.

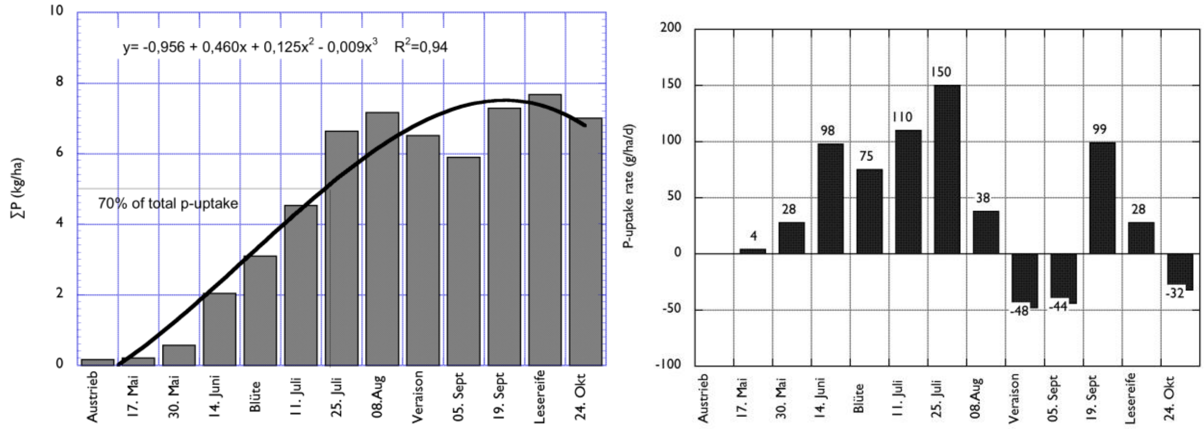

Fig. 7: Total P uptake (left graph) and time rate (right graph) of grapevines during a growing season (Schaller and Löhnertz, 1992)

The amounts of P, which are accumulated during berry development, are shown in right graph. The strongest P sink are the seeds. Pulp and skin reach during the ripening process similar values but considerably lower than in seeds. Other results show that a permanent grass cover results in lower P contents in pulp and skin compared to the above findings.

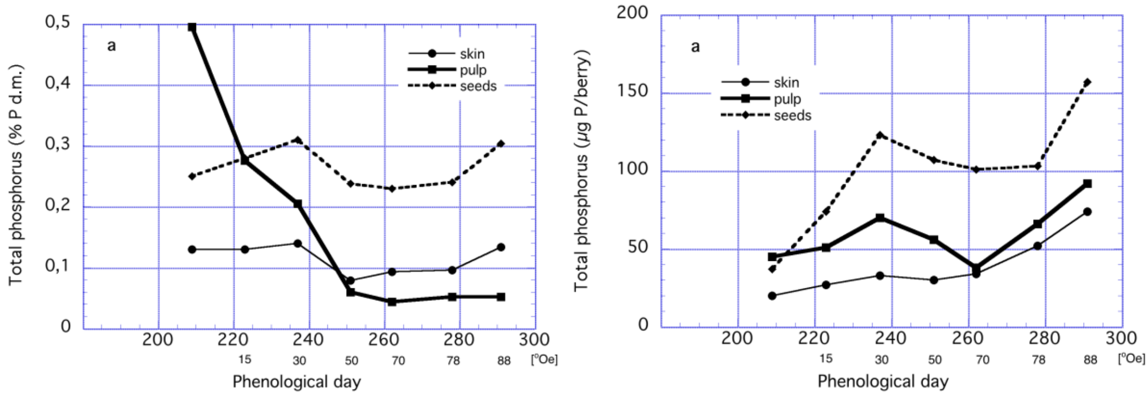

Fig. 8: Time course of phosphorus storage in berries (c.v. Riesling) on dry matter (left) and berry basis (right)

P is besides N an important nutrient for yeast during fermentation. If P is a limiting factor, the impacts on this process may be substantial. Currently it is not known how P contents of musts may control the fermentation. Speciation of P in the musts may also have a certain importance.

The total uptake of P by grapevines is roughly 8 kg P/ha. It occurs during the first phases of development and ceases two weeks after bloom. P should be slightly assimilable for grapevines, i.e. **small** amounts should be fertilized every season or the soil P-pool has to be partially solubilized with the help of intercrops or green manure.

Potassium

Older literature specifies potassium as the most important factor for grapevine quality or of musts. Rationale is, that K favours carbohydrate synthesis and accumulation; therefore grapevines are potassium-philic plants. Fertilization in the past ranged from 150 to 300 kg K/ha. The total K uptake during a growing season is shown in fig 9 (left) and reaches 80 kg K/ha and exceeds N uptake by more than 10-15 kg/ha.

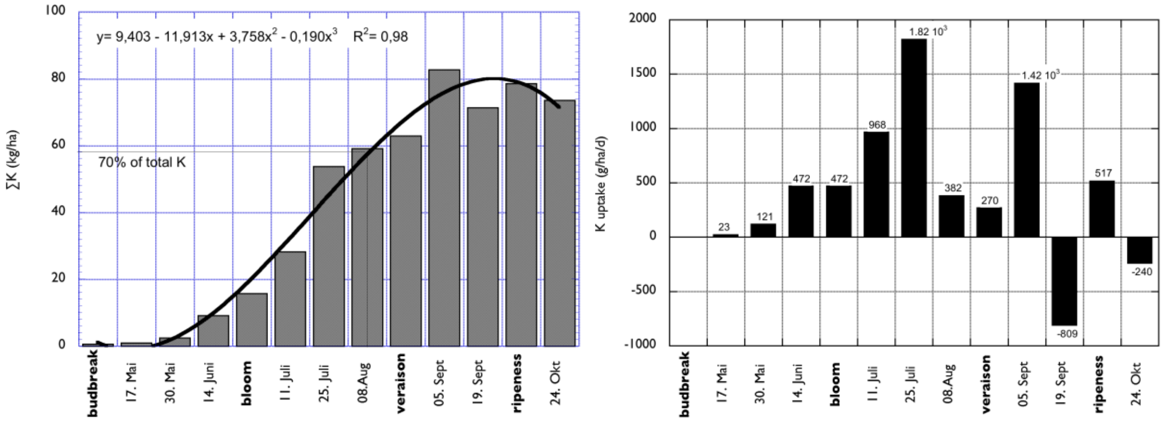

Fig. 9: Total K uptake (left graph) and time rate (right graph) of grapevines during a growing season (Schaller, Löhnerz and Chikkasubbanna, 1992)

K uptake rhythm is shown in Fig 9 (right). Most of K is taken up after bloom with rates of 1, 8 kg K/ha x day. 70% of K is assimilated before veraison. It declines after veraison and approx. 4 weeks before ripeness a further uptake peak occurs. In accordance with this pattern soils should have enough reserves combined with a proper soil humidity to foster the uptake.

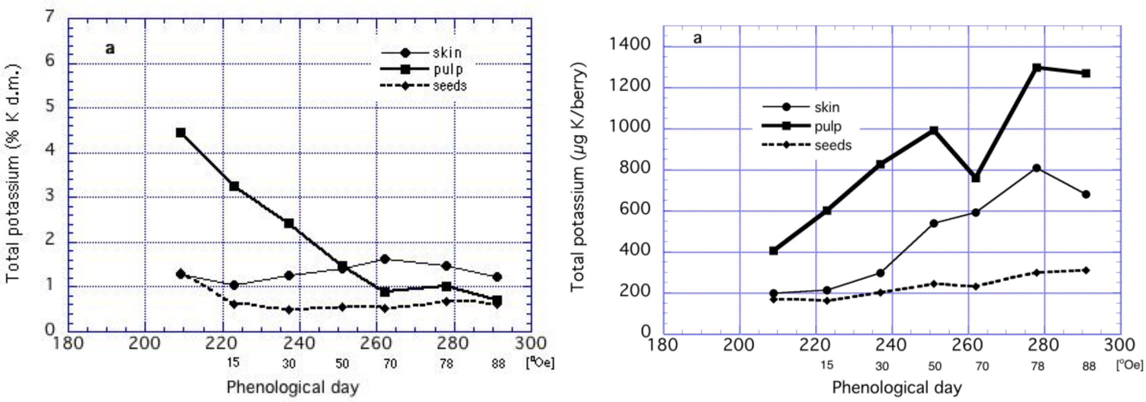

Fig. 10: Time course of potassium storage in berries (c.v. Riesling) on dry matter (left) and berry basis (right)

Concentration of K in developing Riesling berries demonstrates Fig. 10 (left). As with N and P at the beginning K is highest in the pulp. It decreases very fast with progressing development. K in skins and seeds is constantly low. At harvest highest K concentration is found in skins followed by the pulp. Examining K contents on a berry basis (Fig. 10, right) it is seen that the pulp is the main K sink followed by the skin. Most of the berries' K is located in the pulp; also considerable amounts are found in the skin. Worth noting, Potassium is not bound into organic structures but is either adsorbed on organic molecules or functions as a partner to compensate excessive charges resulting from organic anions. The extraction of K during pressing and the transfer into the must is governed by diffusion and disintegration of cellular structures to release potassium. So far, enology can more or less manage important parts of future wine quality. Potassium is also an essential and important nutrient for grapevines. In the foreground of its action the influence on carbohydrate metabolism is a major point. Noteworthy is its influence on an improved disease resistance, esp. fungus diseases.

The total uptake of K by grapevines ranges between 75-85 kg K/ha. Main uptake period by grapevines spans from 5-6 leaves unfolded up to pea sized berries.

It is necessary to maintain enough assimilable K in the soil solution. This can be achieved by improving the water holding capacity of the soil and a continuous supply of the vineyards with potassium. Intercropping and green manure may help to enhance these efforts.

CONCLUSION

Knowing the real amounts of nutrient uptake and its uptake rhythms enables growers to implement an environmentally sound production system and food technologists to install proper production chains in order to produce high quality wines. Further, technology has to develop specific steps during processing to transfer important parts of the nutrients to the must to improve quality. If some nutrients show a particular speciation is still in question, but could improve the know-how for the production of high quality wines.

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