CHARACTERIZATION OF VINEYARD SITES FOR QUALITY WINE PRODUCTION - GERMAN EXPERIENCES

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1.Introduction

The quality of grapevines measured by yield and must density in the northern part of Europe - conditons can be characterized as a type of "cool climate" - vary strongly from year to year and from one production site to another. One hundred year observations in Johannisberg from 1890 to 1991 demonstrate for the yield formation a clear dependancy from the year combined with a steady increase in productivity; latter a proof of positive clonal selection efforts. A similar and also pronounced time series is available for the must quality: Obviously are dramatic changes between the years. They happened during low yielding periods as well as in those with higher yields. The often forwarded claim that higher yields will depress must quality cannot be confirmed despite such long term observations.

Differences in must densities measured in °Oe ranging from 30 to 50 °Oe are not unusual. An explanation for this behaviour may be changes of weather conditons during critical phenological stages of the grapvines development (2,3,5). In a time series recording the stage of full bloom for "White Riesling" from 1947 to 1991 it can be demonstrated that the earliest onset of this stage is on julian day 159 and the latest on day 191, i.e. a span of one month. A similar course can be shown for the phenological stage "begin of ripening": it is reached earliest at julian day 222 and latest at day 261, i.e. a range of more than one month.

These influences can be categorized as "macro climatic" influences. According to them the different grape growing areas can be differenciated, because the nothern viticultural areas differ stronger in must quality from year to year in comparison to the southern growing areas. The second scaling deals with spatial and time dependant variability in a growing region. Main factors depend on topography, soil type and climate.

The influences of both categories on must quality as well as on acidity will be described subsequently.

2. Macroclimatic Influences

As well as the quality also the onset of the different phenological stages grapevines pass varies from year to year. In order to elucidate this interrelations the growing season is divided in (the most important) stages which affect most growth and performance and to relate them to the prevailing weather conditons.

Six relevant developmental stages were found out to be significant, using the scheme proposed by EICHHORN and LORENZ (1) consisting originally of 23 stages.

The three main developmental stages "bud break - full bloom", "full bloom - veraison", "veraison - harvest" are devided in two additional subphases, finally resulting in 6 stages. The weather conditions are related to these six developmental stages for the period 1947 - 1984. The calculation were made with the help of a linear regression with must density as dependant and the weather conditions as independant variables (Tab. 1). The following variables were used for the calculations: (a) a variety specific and weighed optimum curve for the temperature maximum; (b) direct solar radiation; (c) precipitation; (d) saturation deficit; (e) climatic water balance

Tab. 1: *Macroclimatic factors influencing must quality during the production period 1947-1984 in Johannisberg.*

Factor	Coefficient of determination [R^2]
Full bloom (julian day)	46%
Max. temperature during phase 4	16%
Rainfall during phase 6	10%
Water balance during phase 5	10%
Max. temp./rad. during phase 6	9%
Unexplained (rest)	9%

The main share of quality formation is in the stage "full bloom" with 46% (Tab. 1), followed by temperatures during berry growth before veraison with 16%. The climatic water balance in combination with the saturation deficit in stage 3, which represents the most rapid growth period of berries, and the climatic water balance in stage 5, influence must density with 10%. During the following ripening period temperatures and solar radiation are responsible for 8% of the must density formation. A comparable calculation can be made for the phenological phase "full bloom. The most important factor is the stage of "bud burst" with 37%, followed by the temperature in phase 1 (30%), temperature in phase 2 (14%) and the rainfall in phase 1+2 (6%).

The percentages of the different weather variables shown in table 1 and those explained for the stage "full bloom" do not offer any information about their importance and their direction of action. Those are listed in table 2.

It can be seen that an eight days earlier bloom increases at least the must density for 6 °Oe; a 1 °C increase of temperature in stage 4 has a simular influence, and an increase of the daily solar radiation income of 160 Joule/cm² combined with a temperature increase of 1.9 °C, raises the must density for 7 °Oe.

Also a sufficient water supply in stage 3 (saturation deficit and climatic water balance) increases the must density. In contrast rainfall during the ripening period reduces the expectations for a good and sufficiant quality. During the stage 5 the influence of this factor is of minor importance: - 2 °Oe occurs through an increase of the water balance of 2 mm/d. In the stage before harvest raising the water balance for 1 mm/d reduces the must density by 5 °Oe.

Tab. 2: *Effect of different variables on the changes of must quality (°Oe) of cv. Riesling [Postulated variation range: +1 standard deviation]*

Variable	Variation range	Influence on must density (°Oe)
Full bloom	+ 8 days later	- 6.2
Maximum temperature in phase 4	+ 1 °C	+ 6.2
Water Balance, Saturation deficit in phase 3	+ 1. mm/d + 3.9 hPA/d	+ 8.7
Rainfall in phase 6	+ 0.96 mm/d	- 4.6
Solar Radiation, Maximum temperature in phase 6	+ 162 Joule/d + 1.87 °C	+ 7.4
Rainfall, Water balance in phase 5	+ 0.71 mm/d + 1.24 mm/d	- 1.9
Phase 3 = Phenological stage 23 (full bloom) - stage 29 (pea sized berries) Phase 4 = Phenological stage 29 (pea sized berries) - stage 35 (veraison) Phase 5+6 = Phenological stage 35 (veraison) - stage 38 (ready for picking)		

With an average duration of 20 days in this phenological stage a total 20 mm of rain is achieved. Those close relationships cannot be found between yield of grapevines and weather. It was not also possible during the analyses of this time series to detect relationships between yield and quality.

3. Mesoclimatic influences

In the northern grape growing areas an important influence on the quality besides the yearly weather conditions results as well from the spatial variables and their timely distribution.

These influences were investigated since 1960 on 125 test plots. Since a direct measurement of the mesoclimate was not possible on all locations, the discrimination of the sites against each other is made with variables derived from calculation models. The following variables are used for this process: (a) direct solar radiation income (KJoule/cm^2); (b) temperatures during night and day dependant from exposition and; (c) height above sea level; (d) cold air exposition is available for every location in a special map. Methods are described by HOPPMANN (4).

Comparable to the analyses made for the time series 1947-1948, also in this test series the thermic conditions are the most important factors for the formation of quality. Integral part of these methods is the calculation of the energy income from the direct solar radiation during the growing season from April to October (4).

Without going in depth of the model calculation, it can be demonstrated that e.g. a northern orientated plot with an inclination of 10° receives less 37 KJoule/cm^2 x growing season from direct solar radiation than a comparable south orientated one. This results in an average of ten years in a difference in must density of roughly 10 °Oe.

The decrease of temperature with height - which is also dependant from expostion and inclination of a vineyard site - controls most important the formation of quality. Tab.3 elucidates exemplarily these relationships. The calculated daily temperature during the stage "veraison - harvest" is shown in column Td*.

Tab. 3: *Influence of site parameters on must density (°Oe) in cv. Riesling (10 years average)*

slope exposition	slope inclination	height a.s.l.	must density (°Oe)	Td*
SE	20	245	71	13.6
SE	04	218 (windy site)	61	12.8
SW	07	211	73	13.7
S	18	170	77	14.3
S	23	145	83	14.5
S	03	110 (cold air)	67	13.4

*Td = average daily temperature during phase „veraison-ripening"

The topographical datas of the locations are indicated in the first 3 columns. The plot with an inclination of 23° to south and a height of 145 m a.s.l. has in a ten years average a must density of 83 °Oe by an average daily temperature of 14,5°C during the ripening stage. The site located 100 m higher a.s.l. has a temperature 0.9 °C lower and as a consequence the must density is lowered to 71 °Oe (- 12 °Oe) in a ten years average. A higher wind exposition or cold air reduces the temperature and (as a strict consequence) the must densities.

Radiation and temperature can be merged and described with the help of an empirical method, plotting the decrease of temperature with height a.s.l. against the falling energy income.

In a multifactorial analysis with ten years means it was tried to elucidate the influence of different et climatic and pedelogical parameters on must density and acidity.

4. Pedological parameters

The discussions which are contributed to the influence of climatic conditions and/or the vineyard sites culminate in the concept of the "terroir". There is also more or less a generally accepted agreement that the different production sites have a distinct influence on the overall quality of the wines. To verify or to discard such a hypothesis yields, must quality and also must acidity of the 125 testplots were related with some common soil parameters.

Tab. 4 indicates clearly that in flat - slightly sloped areas roughly 36% of the variability of must density is determined by the solar radiation income, 4% by the height a.s.l. and additional 7% from cold air influences. Other variables like plant available water, soil type and trunk height are neglectable, ranging only from 2-4% each.

In the steep slopes, which are characteristic for great parts of German viticulture, the height a.s.l. determines with 40% the must quality, followed by plant available water with 11%, and at least the solar radiation with 6%.

Tab 4: *Influence of pedological and climatic parameters on must quality in differing sites. Contribution (%) for the explanation of the variabilty of must density. (10 years average 1964-74)*

Site characteristic	independant variable	% contribution (R^2 x 100)
flat	□ rad. (Apr - Oct)	35.8
	altitude a.s.l.	3.9
	cold air	6.5
steep	altitude a.s.l.	39.9
	plant avail water	10.6
	□ rad. (Apr - Oct)	6.3

The relationships (figures not shown) between must acidity and site specific parameters indicates that in the flat-slightly sloped production sites the same parameters are responsible and 45% of the acidity's variability can be explained, but it must be indicated that between height a.s.l. and solar radiation income exists a strong interrelationship. In the flat-slightly sloped areas exists a positive relationship between canopy height and acidity. The reduced direct insolation of the leaves with increasing canopy heigth may be responsible that especially during the month September - October where ripening occurs the dissimlation of acidity is slowed down.

In contrast, in the flat-slightly sloped areas, which didnot suffer in plant water availability, more or less soil nutrient factors are dominating with magnesium, nitrogen and C/N ratio. Plant available water ranks in an inferior place with a low importance (5%).

The influence of pedological factors is demonstrated for these test sites and for the complete test period (tab. 5). It can be seen that in flat as well as in steep sites the factor phosphorus content in the subsoil determines 22 % of the must density variability. In the second place ranges the potassium content of the subsoil with 3,2% in flat sites, whereas in the steep ones the N content of the topsoil contributes 15% to the explanation of must density variability. In both sites 30-40 % of the variability can be explained with 3 independant soil parameters.

It can be seen that the P-content of the subsoil is the dominating factor; it is important for the sugar accumulation in berries and the dissimilation of acids during the ripening process. It is worth to note that phosphorus seems to be a metabolic key in quality formation of grapevines under cool climate conditions.

Tab. 5: *Influence of pedological parameters on the must density [°Oe] in differing sites. Mean of ten years. Contribution (%) for the explanation of the variabilty of must density (ten years average 1964-74)*

Site characteristic	independant variable	% contribution (R^2 x 100)
flat	P (subsoil)	22.1
	K (subsoil)	3.2
	K (topsoil)	7.3
steep	P (subsoil)	20.6
	N % (topsoil)	15.1
	P (topsoil)	5.3

Tab. 6: *Influence of pedological parameters on the must acidity in differing sites. Mean of ten years. Contribution (%) for the explanation of the variabilty of must acidity (ten years average 1964-74)*

Site characteristic	independant variable	% contribution (R2 x 100)
flat	P (subsoil)	30.1
	Mg (topsoil)	12.8
	pH (subsoil)	1.6
steep	P (subsoil)	11.3
	P (subsoil) $CaCl_2$	9.0
	pH (topsoil)	11.4

The overall influence of soil factors is demonstrated in calculations made with the means of ten years (Tab. 7). All plots from the Rheingau region are used to elucidate the influences of soil parameters on yield and quality parameters in grapevines.

It can be seen that yield formation is a multifunctional event, because the contributions of the different soil factors are with exception of the subsoil pH equally distributed on subsoil and topsoil parameters. The importance of the pH is quite obvious because it is responsible for nutrient availability as well as for the mineralization process of organic matter, which more or less pushes the growth of grapevines. In the case of must density there is a considerable influence of the phosphorus content of the subsoil; explains 24% of the must density variability. The vast rooting system of the grapevine is dependant of a good P supply in the deeper rooting zones, in particular when the vine have established after a longer period of growth.

Tab. 7: *Influence of pedological parameters on the must quality in differing production sites. Mean of ten years.*

Factor	independant variable	coefficient	% contribution (R^2 x 100)
yield [kg/m2]		6.223	
	pH (subsoil)	+0.033	9.5
	K_2O (subsoil)	+0.116	4.6
	%C (topsoil)	-0.335	4.8
	%N (topsoil)	+44.476	2.0
	Mg (topsoil)	-0.417	2.3
	%N (subsoil)	+159.84	1.4
must density		60.963	
	P_2O_5 (subsoil)	+0.091	24.3
	K_2O (subsoil)	-0.223	6.1
	K_2O (topsoil) $CaCl_2$	+0.176	2.4
	P_2O_5 (subsoil) $CaCl_2$	+0.002	1.8
	%N (topsoil)	-40.228	1.6
	pH (subsoil)	+0.138	1.3
must acidity		17.45	
	P_2O_5 (subsoil)	-0.02	25
	Mg (topsoil)	-0.015	8.4
	C/N (subsoil)	+0.029	1.7
	P_2O_5 (subsoil) $CaCl_2$	+0.001	1.2
	K_2O (subsoil) $CaCl_2$	+0.057	0.7
	K_2O (topsoil)	+0.048	0.9

Most impressive is the inverse relationship with must acidity: 25% of its variabilty can be explained with the varying P content of the subsoil. A further increase in explanation is obtained by the Mg content of the subsoil which is also negatively related to must acidity.

5. Synoptic combination of mesoclimatic and pedological informations

The experiences about mesoclimatic and pedological influences on quality of musts can be combined in "synthetic maps". In the Rheingau region for more than 40 years soils are mapped in a scale of 1:5000 (6). With the additional informations about meso- und macroclimatic influcences on quality formation, maps can be constructed which show the influence of solar radiation, temperature and soil on a distinct production site. The results of soil mapping, mesoclimatic model calculations and the means of ten years yield and must quality measurements are merged in this synoptic map. In the legends detailed information is given about soils, soil types and recommendations for the choose of different rootstocks.

Besides the soil classification 3 climatic zones for grapevines are developed; i.e.

- **zone A** = locations with a long climatic favourable growing season (recommended varieties Riesling, Pinot noir)
- **zone B** = locations with a reduced climatic growing season (recommended variety Müller-Thurgau)
- **zone C** = not suited for grapevine growing

These informations can be used from growers, extension service, consultants and also (political) decision makers to influence development of viticulture in a economic, socio-economic or cultural way. During the last years a lot of the processes underlying these observations were modelled and can be used for a better understanding of the grape growth, quality formation and the zoning of vineyards. The latter process should be done after our opinion with reliable methods as a basis, because it should be very hard to copy such a system like the French one, which has a quite different basis. Under contemporary conditions and especially with the scientific progress in mind, it is necessary to look for a sound scientific basis of the zoning process. Whenever it is needed.

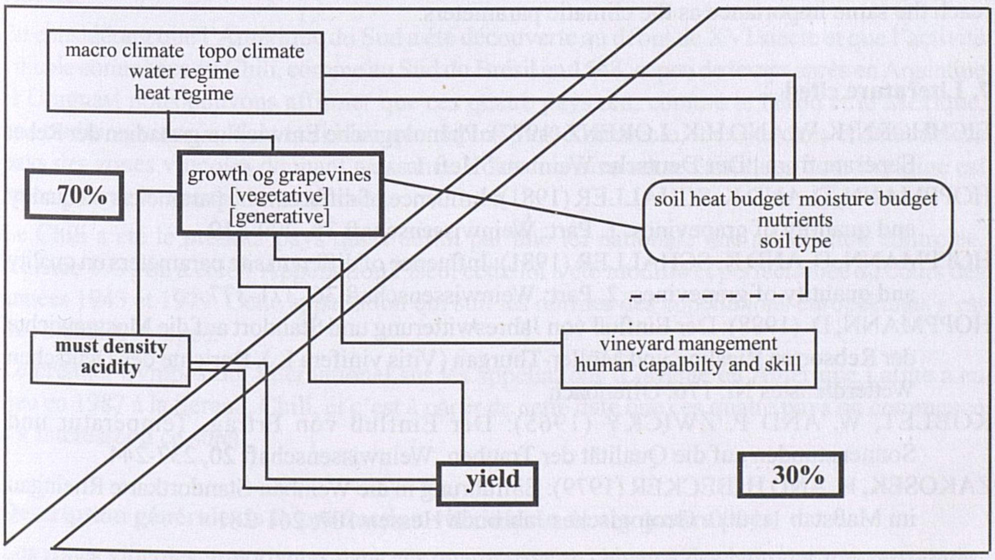

Fig. 1: *Flow chart of the climatological, pedological and human factors which influence quality formation of grapevines under northern European conditions.*

Summarizing all the factors which are responsible for yield formation and must quality in northern grape growing areas it can be stated that the overwhelming part is played by the climatic conditions (Fig. 1): 70% of the variability of yield, must density and acidity is determined by climatological factors and more or less 30% by pedoligical and/or human factors. The latter may act indirectly but nevertheless can be a strong factor.

The future task will be to elucidate the interrelationships between climate, plants perfromance and human activities in order to get an understanding of the production systems and the underlying processes. Afterthen it might be possible to develop a model with which a sort of zoning can be made.

6. Conclusion

These long-term investigations in the Rheingau region demonstrate very clearly, that the quality buildup in grapevine production in the northern European areas is strongly dominated by the solar radiation income and the temperature regime as well in the macroclimatic as in the mesoclimatic scale. The detailed information and the results allow the quantitative construction of maps demonstrating the influence of the production sites. Problems of water availability are not important under "cool climate" conditions. These may be play a rôle in the "mediterranian" climate and can be used for a classification of those production sites. But on the other hand it may be pointed out, that in very dry years "water" may be become also important under "cool climate" conditions. These relationships shown for different years, may indicate that drought production sites, i.e. in mediterranean areas, emphasis may shift from temperature to soil water budgets. The actual and available information basis allows to develop for those regions well suited climatic and soil maps. The interelationships between grapevine and soil are not so strictly elucidated, as those between quality formation and climatic conditions.

As could be demonstrated for a ten year average principally more or less heavy available nutrients seem to influence the quality formation in grapevines. On a one year scale different parameters, mainly ready available nutrients are indicated to influence the quality build up. It is also interesting that these soil parameters can only explain ca. 40% of the variability of must density and never reach the same importance as the climatic parameters.

7. Literature cited

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