Role of Harvesting Time/Optimal Ripeness in Zone/Terroir Expression
Rôle de la Date de Récolte en relation avec la Maturité optimale et l'Expression du Terroir

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Abstract
Optimal ripeness is defined according to the style of wine that is required. The latter is ultimately dictated by the market. Soil and climate may have a dictating effect on typical expression of wine. The level of grape and wine quality achieved and the potential for obtaining different styles of wine are determined by the integrated effect of the natural characteristics of the terroir and technological intervention (long and short term cultivation practices). The growth conditions that the grapevine is subjected to should allow optimal metabolic activity in roots, permanent structure, canopy and grapes and the potential for these organs to develop and support each other until the desired grape quality and style is reached. Monitoring of morphological and physiological parameters in the canopy and grapes, ultimately displaying the integrated effect of the growth environment, is critical in our quest for finding indicators that may be associated with a particular grape and wine style. This has not been systematically investigated.

Results of collaborative research done on a Shiraz/R99 vineyard in the Stellenbosch region, South Africa, with the purpose of defining environmental, canopy and grape parameters that may be suitable as eventual practical indicators for obtaining particular styles of grapes and wine, are presented. Vines were vertically trellised and spaced 2.75 x 1.5 m in north-south orientated rows on a Glenrosa soil and a west-facing slope. Microsprinkler-irrigation was applied at pea berry size and at vèraison stages. The 1.4 m canopies were shoot-positioned and topped. Fortnightly sampling was done from berry set up to two weeks post-véraison, after which harvesting for wine making was done approximately every four days. Microclimate, vegetative, reproductive and physiological parameters were investigated and changes during alcoholic fermentation monitored at each harvesting stage. Wines were made and analysed. Similarities in patterns as well as various ratios between the different parameters were investigated. Results are argued against canopy performance, carbon allocation, water relations, production level, and sugar, acidity, anthocyanin, phenolic and tannin contents of the grapes as well as wine quality and composition. Ratios for potential practical use in determining optimal grape quality, time of harvesting and expected wine style are discussed.

Résumé
La maturité optimale est définie en fonction du style de vin désiré, qui est fonction du marché. Le sol et le climat ont un effet sur la typicité des vins. Le niveau qualitatif des raisins et des vins, et le potentiel pour obtenir différents styles de vin est déterminé par l'association des caractéristiques naturel du terroir et les technologies mises en œuvres (i.e. les pratiques culturales à moyen et long terme). Les conditions de culture de la vigne doivent permettre une activité optimale des racines, des structures pérennes, de la canopée, des grappes et favoriser l'équilibre entre ces organes jusqu'à l'objectif final : des raisins de qualités différentes pour des styles de vin différents. La gestion et l'analyse des paramètres morphologiques et physiologiques de la canopée et des grappes, dans un environnement donné, est indispensable pour trouver les indicateurs qui peuvent être associés à une qualité de raisin et un style de vin. Ce point n'a pas été systématiquement étudié.

Dans cet article, un bref rappel de l'impact potentiel du terroir et des pratiques culturales court et long terme sera donné. La partie principale indiquera les résultats d'une collaboration de recherche faite sur Syrah/99R dans un vignoble de la région de Stellenbosch, Afrique du Sud. L'objectif a été de définir les paramètres de l'environnement, de la canopée et des grappes utilisables comme indicateurs pratiques et pertinents de la qualité du raisin en relation avec un style de vin. Les vignes sont conduites en Espalier (2,75m x 1,5m), les rangs sont orientés nord – sud, le vignoble est en pente orientée est. Une irrigation par micro aspersion est appliquée de la nouaison à la véraison. La hauteur de végétation est de 1,4 m, avec 2 hauteurs de fils de palissage. Les vignes sont palissées et écimées. Des prélèvements ont été réalisés tous les 15 jours depuis la nouaison jusqu'à la véraison. A partir de la véraison (14°Brix) des prélèvements de raisin ont été réalisés tous les 4 jours et jusqu'à sur-maturation, pour réaliser des mini vinifications. A chaque stade de prélèvement les paramètres du microclimat ont été mesurés. L'évolution végétative, reproductive et physiologique de la plante a été étudiée. Les fermentations ont été contrôlées pour chaque mini-vinifications. Les vins ont été analysés. Les similitudes et les variations dans l'évolution des paramètres et leurs ratio ont été analysées et interprétées.

Les résultats sont discutés en relation avec la performance de la canopée, l'allocation de carbone, les relations avec l'état hydrique de la vigne, le rendement, ainsi que le contenu en sucre, en acides organiques, en anthocyanes, en phénols et en tanins totaux des baies. L'ensemble est corrélé à la qualité des vins et à leurs composition. Les ratios des indicateurs sont testés pour déterminer la qualité optimale du raisin et la date de vendange en relation avec le style de vin. La pertinence et l'applicabilité des indicateurs sont discutées.

Introduction
World-wide, many styles of wine exist that are judged by the general consumer and the wine expert, both of whom are very important in quality classification, marketing and selling of a particular wine. Although the grape composition and winemaking procedure are eminently dictating the final product, a particular style of wine should be directed by market requirements. Optimal ripeness for a particular style of wine is therefore also ultimately dictated by the market and the result of a three way communication (grape producer, winemaker, market). The level of grape and wine quality achieved, the expression of a typical terroir-related character in the wine and the potential for obtaining different styles of wine are determined by the integrated effect of the natural characteristics of the chosen terroir (soil and climate) and technological intervention (long and short term cultivation practices) (Jackson & Lombard, 1993; Calò *et al*., 1996; Hunter & Archer, 2001a, 2001b; Deloire *et al*., 2002). This is applicable to a single vineyard or different vineyards, the latter which may lead to viticultural zoning.

Monitoring of morphological and physiological parameters in the canopy and grapes, displaying an integrated effect of the growth environment (aboveground and subterranean), along with wine composition and sensorial quality, are critical aspects in our quest for finding indicators that may be associated with a particular grape and wine style. Despite the crucial importance of the latter for viticulture and oenology and the essentiality of timely harvesting for a quality product, it has only been occasionally studied/reviewed (González-San José *et al*., 1991; Lacey *et al*., 1991; Calò *et al*., 1996; Ribéreau-Gayon *et al*., 2000; Bisson, 2001; Hunter *et al*., 2004). The accumulation patterns of secondary metabolites (e.g. phenolic compounds, flavour compounds, anthocyanins, proteins and

glycosidically-bound secondary compounds) in maturing berries received the most attention (e.g. Gholami *et al*., 1996; Downey *et al*., 2003; Hilbert *et al*., 2003; Hunter *et al*., 2004). To our knowledge, a purposeful and systematic investigation over a wide range of ripeness levels, involving physiological and morphological measurements on the canopy and grapes as well as wine composition and quality, and with the purpose of finding practical indicators of optimal harvesting points and different wine styles, has not been done before. Such a study is critical in order to, amongst others, fully express the potential of a particular terroir in the eventual wine quality, irrespective of wine style required.

It is envisaged that the study will contribute to understanding the relationships between leaf (source) and grape (sink) seasonal metabolic changes and optimal grape and wine quality. The objectives of the study were to determine the importance of different seasonal growth phases for grape and wine quality and grape parameters and ratios of selected grape chemical constituents at different levels of ripeness that would indicate an optimal harvesting time as well as different styles of wines. In this way, practical parameters that would enable producers to manipulate and judge optimal grape and wine quality associated with a particular style may be found.

Materials and Methods

Vineyard and viticultural practices

A seven-year-old *Vitis vinifera* L. cv. Shiraz (clone SH1A) vineyard, grafted onto Richter 99 (*Vitis Berlandieri* x *Vitis rupestris*) (clone RY2A), was used. The vineyard is located on the Experiment Farm of ARC Infruitec-Nietvoorbij in Stellenbosch (Western Cape). The area is affected by a Mediterranean climate. The vines are spaced 2.75 m $\times$ 1.5 m on a Glenrosa soil (Soil Classification Working Group, 1991) with western aspect (26^{o} slope) and trained onto a 7-wire (cordon wire and three sets of movable wires) Lengthened Perold (Vertical Shoot Positioned) Trellising System (Zeeman, 1981). Vines were micro-sprinkler irrigated at pea size and at véraison stages (12 hours @ 32L/hour). Vines were pruned to two-bud spurs with a spur spacing of approximately 15 cm. Rye was used as cover crop during winter. Normal cultivation practices for the production of healthy grapes were used.

Treatments

Vines were all similarly pruned and the canopies shoot positioned and topped (Hunter, 2000). Shoots were vertically positioned in line with corresponding spurs. Topping (30 cm above the top wire) was done twice during the period berry set to pea size and comprised the removal of up to 30 cm of shoots. Ripeness level harvesting dates were replicated three times. Ten vines per replicate were used until 14 days post-véraison and 15 vines per replicate there after. In total, sampling was done at 19 dates, including 16 harvesting dates for winemaking purposes (from 14 days post véraison).

Measurements and analyses

Canopy dimensions and microclimate, soil water, canopy growth and physiology, and grape growth and composition were monitored from 14 days after berry set stage at two-week intervals from separate groups of vines until 14 days post-véraison. During the last stages of ripening, parameters were monitored approx. every 4 days and wines were additionally made of each harvest during this period. Seven shoots (with bunches) per replicate and sampling/harvesting date were randomly selected and used for all vegetative and reproductive determinations and chemical analyses. Wines were made from a minimum of 40 kg grapes per wine. Microclimatic parameters in the bunch and canopy were continuously recorded during the whole grape monitoring period by means of probes and data loggers. Levels of grape constituents obtained during the first phase of the berry growth period (up to véraison) were correlated to levels obtained during the last stages of grape ripening. Grape parameters and ratios of the different components analysed were correlated with wine sensorial quality results in order to identify factors that would be best suited as indicators of harvesting points for different styles of wine and which may be used to predict different wine sensorial quality characteristics.

Photosynthetic activity of primary and secondary leaves close to the bunch zone was measured during mid-morning (from 10:00) using an open system ADC portable photosynthesis meter (The Analytical Development Co., Ltd., England). Leaf and stem water potential of primary and secondary leaves was

determined during early afternoon using a pressure chamber (Scholander *et al*., 1965). Primary and secondary shoot length, leaf mass and area, bunch and berry mass and volume, and berry pedicel, brush and seed browning were determined at all stages. Light intensity in the bunch zone of the canopy was measured during mid-morning by means of a LICOR Line Quantum Sensor. The canopy dimensions and microclimate were visually scored (Hunter, 1999 - based on that of Smart *et al*., 1990).

Total soluble solids (^{0}B), total titratable acidity (as g/L tartaric acid), and pH were analysed according to standard methods. Malic and tartaric acid as well as sucrose and glucose in leaves (primary and secondary), whole berry, berry pulp and berry skins were extracted and analysed by GLC according to a method described by Hunter & Ruffner (2001). Skin anthocyanins and total phenolics were extracted and determined according to Hunter *et al*. (1991). Whole fresh berry anthocyanins, tannins (skins and seeds), total phenolic index, colour intensity, and hue/tint were extracted and determined according to the methods described by Ribéreau-Gayon *et al*. (2000) and Cliff *et al*. (2002). Wines were analysed using the same methods. Amino acids were analysed by gradient high performance liquid chromatography (Bidlingmeyer *et al*., 1984; Rautenbach, 1999). Free-amino-nitrogen (FAN) in the must was determined according to an Auto Analyzer method using ammonium sulphate as reference (Anonymous, 1974).

Grapes of all harvests were cooled to the same temperature (20 ºC) before processing. Whole berries, skins, seeds, pomace and wine were analysed for each ripeness level. Grapes were destemmed, crushed and the pomace inoculated with commercial yeast (VIN 13). Alcoholic fermentation took place at a controlled temperature of 24 ºC (di-ammonium phosphate and SO_2 were added). The skins were pushed through three times per day. Fermentation on the skins averaged five days, after which the pomace was pressed. Skins and pomace were analysed during fermentation on the first, second, fourth and fifth day after crushing (seeds were only analysed on the fifth day after crushing – data not shown in this paper). Evolution of colour density ($A_{520 + 420}$) and total phenolic content (A_{280}) was monitored in the pomace and skins. Total flavan-3-ol (catechin tannin) (DMAC analysis) was determined in the seeds from intact berries and after pressing. Wines were made similarly. The degree of alcohol, phenolics, colour intensity, and colour density were determined in the different wines. Wines were made similarly and were organoleptically evaluated by a trained panel. In addition, wines were analysed for anthocyanin, tannin, and phenolic contents (also directly after the skin contact period).

Statistical layout and analyses

The experiment was laid out as a randomised block design with three block replications. The treatment design was a 2 x 19 factorial with factors being two treatments [control and canopy management (not described)] and 19 harvesting times. Sensorial evaluations of wines were done using four seven-member panels, each tasting all replications of the different ripeness levels. Measurements were taken for three growth seasons. In this paper, data of the control treatment for the last two growth seasons are presented. Trends of variables and ratios during the season for the control treatment were compared for two growth seasons and combined if necessary. Coefficients were compared using t-test. Moving averages were used when data were presented on figures. Variables with significant trends were selected and correlated with wine sensorial evaluation quality variables. Stepwise regression was performed to select the best subset of variables to predict different wine quality variables. Grape parameter and ratio groups for the identification of distinct wine styles were compared using t-test. A significance level of 5 % and less was applied to all data.

Results and Discussion

The growth conditions and basic canopy management (e.g. trellising, shoot positioning & topping) allowed the attainment of primary shoot lengths of 1.2 - 1.3 m, carrying 13 – 16 leaves, which were almost perfectly inside the general criteria for obtainment of high quality grapes as suggested by Hunter (2000) and Nadal *et al*. (2001) [(basic canopy management normally shifts the canopy composition balance (mostly additional secondary shoot growth) to a more favourable situation in terms of canopy function, continued canopy support to grapes, and grape quality – see also Hunter (2000) and Hunter *et al*. (2004)]. Radiation intercepted above the canopy and reflected from the soil into the canopy was highest in October (during bud break) and lowest in March (during late harvesting) (data not shown). Despite that, canopy temperatures increased during this time until February and bunch temperatures

until March (February is normally the hottest month during the harvesting period in South Africa) (data not shown). Bunches were not directly sun-exposed, which is generally accepted as being preferable in terms of grape quality. Similar trends were found for vertically trained canopy management treated Chenin blanc vines (Volschenk & Hunter, 2001).

Primary shoot length already stabilized from around berry set/pea size when topping started (data not shown). In both growth seasons, primary leaf area showed a decline (senescence) from around 8 weeks after véraison, whereas secondary shoot leaf area was maintained for the whole harvesting period (Fig. 1a & 1b). Secondary shoot leaves in the canopy generally photosynthesised at a much higher water use efficiency (WUE), thereby increasing WUE of the whole canopy [see also results of Hunter & Visser (1988) and Hunter (2000) for Cabernet Sauvignon and Sauvignon blanc] (Fig. 2). Interestingly, WUE of vines peaked approximately 8 weeks after véraison for both primary and secondary leaves. Secondary leaves were newly matured during the ripening period and therefore very efficient during this time. This is also evident from higher sucrose production of secondary shoot leaves for most of the season (Fig. 3). Generally, glucose concentrations of primary and secondary leaves were similar and malic acid concentrations of secondary leaves higher than those of primary leaves (data not shown). Lateral shoots effectively sustained canopy sufficiency and led to a higher canopy quality which would provide a buffer capacity against terroir-related stress conditions and facilitate continued contribution to grape composition as well as the permanent structure of the vine for a longer period of time (see also Hunter, 2000). On terroirs with, e.g. low soil water holding capacity and low temperatures during the later harvesting period, and which induce early leaf abscission, lateral shoots would make a significant contribution to grape ripening. Sucrose production by both primary and secondary leaves became restricted during the last harvesting stages (from approximately 8 weeks after véraison). Thus, although leaf area (particularly secondary leaf area) was still largely intact, this would seem to indicate a physiological end point as regards maximum leaf function and support. A further increase in soluble solid content was most probably increasingly dependent on secondary shoot leaves, the reserve pool of the vine and redistribution of carbon.

Bunch mass and volume (data not shown) as well as berry mass and volume (Fig. 4) reached highest values about 3 weeks post véraison, after which mass and volume of berries were reduced by approximately 40 % until the final harvesting date. Except for physiological implications, this also has serious financial repercussions. If a reduction in berry mass (along with other parameters) is to be used as a quality criterium for red cultivars, max./min. sizes should be established for different cultivars and situations along with concomitant quality changes. Payments should be adjusted accordingly. The bunch and berry mass and volume peaks corresponded with the first soluble solid peak (Fig. 5) and also coincided with the first peak sucrose, glucose, tartaric and malic acid concentrations in both primary and secondary leaves (data not shown). This illustrates the fine balance between vegetative and reproductive growth, irrespective of the environmental conditions to which the vine is subjected. This finding has significant implications for grape growing on different terroirs. If leaf production is limited, replenishment of the berry with water and concomitant respiratory substrate (primarily sucrose) would also decrease. In such an event, the berry transpires more water than it can gain from water potential and pressure flow gradients, leading eventually to a metabolic deceleration, berry shrivelling and eventual decay (Greenspan *et al*., 1994; McCarthy & Coombe, 1999; Hunter & Ruffner, 2001). This will also be affected by the extent to which the attraction (metabolic activity) of grapes for supply from the leaves is promoted by bunch microclimate. In agreement with these arguments, the must soluble solid content showed a first peak around 3 weeks after véraison, where after further increases, most probably primarily as a result of concentration, occurred. Similar patterns were noticeable for total titratable acidity (decreasing) and pH (increasing). Seasonal sucrose concentration patterns in the berry showed a remarkable correspondence with soluble solid content, the initial peak concentrations in the whole berry, pulp and skin occurring from 2 weeks (skin) to 3 weeks (berry) after véraison; glucose concentrations first peaked about 1 week earlier (Fig. 6a & 6b). Sucrose concentrations in the berry seemed to increase during the last stages of ripening, most probably because of concentration together with restricted hydrolysis. This corresponded with a decrease in sucrose concentration in primary and secondary leaves (Fig. 3). Despite an increase in plant leaf and stem water potential (data not shown) during this time, berry size was reduced (Fig. 4); support from the leaves to bunches (phloem transport)

apparently became restricted and berries seemed to function more independently. Berry contents seemed to become more and more dependent on physical changes and progressive dehydration (see also Dreier *et al*., 1998; Dreier *et al*., 2000). In general, critical physiological changes in the leaves and berries seemed to occur at approximately 3 weeks and 8 weeks after véraison. Amino acid and total nitrogen patterns in primary leaves, berries and skins showed that proline in particular increased noticeably from véraison to the last harvesting stage (data not shown), indicating stress/senescence. This is in agreement with results found by Hilbert *et al.* (2003). The rest of the amino acids as well as total nitrogen increased in the primary leaves (nitrogen reserve accumulation), decreased in the whole berry (despite the berry size reduction) and mostly kept stable in the skins during the later stages of ripening, clearly indicating reduced transport to the berry pulp (data not shown). Since the presence of amino acids is generally considered to be favourable to fermentation and flavour development in wine (Rapp & Versini, 1996), this would contribute to reduced berry quality during the later ripening stages.

Berry skin anthocyanin and phenolic patterns (based on dry mass extraction) corresponded with soluble solid and hexose patterns of the berry, peaking early during ripening (3 weeks after véraison) with a slight increasing tendency there after up to approximately 8 weeks after véraison (Fig. 7). The anthocyanin released by whole, fresh, crushed berries measured at pH 3.2 [approximately equal to extraction during fermentation (Ribéreau-Gayon *et al*., 2000)] essentially followed similar patterns than those of skin phenolic compounds, peaking approximately 8 weeks after véraison and keeping virtually stable after that (Fig. 8). In contrast, from approximately 8 weeks after véraison, the contribution of seed-tannin increased for a further 2 weeks where after it stabilised, whereas total phenolics and tannin continued to increase until the final harvesting date (similar to berry soluble solids and pH). The flavan-3-ol monomer (catechin) content was also higher during the last harvesting stages. [The difference in anthocyanin curves obtained at pH 3.2 *versus* that obtained at pH 1.0 (at which pH proteophospholipid tonoplast membranes of cells are ruptured, protein bonds broken, contents of vacuoles released and all anthocyanins extractable and solubilised in solution) showed that anthocyanins were not effectively released during extraction at pH 3.2 in spite of their potential availability (data not shown)]. At the same time, the pomace:juice ratio increased, indicating lesser and lesser sap recovery from grapes as ripening proceeded (data not shown). This was also evident from the decrease in berry volume (Fig. 4). Extraction from whole berries was positively affected by the reduction in berry size as ripening continued. Similar trends were found when berries were tasted (data not shown). Although the colour of the rachis, and pedicel and brush of the berry did not change much during the season, seeds changed from a green-brown to white-brown colour and finally to a brown colour.

The extraction of anthocyanin, phenolics and tannin into the wine during fermentation increased the longer the ripening period (Fig. 9a - 9c). However, during the later stages of ripening, extraction seemed to be completed. Both anthocyanins and phenolics in the wine increased with fermentation up to the fourth day. The tannin content of the wine decreased during fermentation. Longer fermentation (up to 20 days) made no further contribution (data not shown).

In the wine, anthocyanin, tannin, phenolic and total flavan-3-ol monomer (catechin) contents as well as hue/tint and redness followed similar patterns to those found in grapes (Fig. 10). Further, sensorial quality of the wine also corresponded with the above findings on the canopy and grapes, clearly showing the emergence of different wine styles as grape ripening proceeded (Fig. 11). The probable alcohol content and residual sugar of the wine continued to increase throughout the harvesting period. Since the seasons differed climatically, the final harvesting dates and number of harvesting dates (11 and 16) for winemaking were also different for the two seasons. However, for both seasons, after approximately 2 months after véraison, there seemed to be no further improvement in any wine quality parameter, including total wine quality impression. In fact, the acceptability of the acidity as well as aroma intensity decreased during later ripening stages. Five weeks to approximately 8 weeks after véraison seemed to be a period during which increasingly more concentrated wines with relatively low eventual wine probable alcohol content were obtained. After this period, no further improvement in grape and wine quality was obtained from leaving the grapes on the vine. In fact, wines obtained additional jammy flavours.

It is hypothesised that basic metabolic changes would be controlled by homeostatic mechanisms. Various ratios of leaf, berry and wine chemical constituents at the different harvesting dates (ripeness levels) were therefore calculated with the purpose of finding indicators of optimal harvesting time as well as different styles of wines, with consideration of the aforementioned trends. In this way, practical parameters that would enable producers to manipulate and judge optimal grape and wine quality associated with a particular style are envisaged. The ratios and other grape parameters were statistically reduced to those showing the best correlations with wine sensorial quality parameters. The eventual grape parameters and ratios and correlations with the different wine sensorial quality parameters are presented in Table 1. The ratios were further subjected to a stepwise regression analysis, showing the grape parameters and ratios that can best be used to predict the different wine sensorial quality parameters (Table 2).

Stepwise regression was also used to identify parameters that would best indicate different wine styles, the result being ratios of berry mass:tannin(whole berry extract), °B:titratable acidity, pH:titratable acidity and °B:tannin(whole berry extract). However, in order to indicate the different wine styles in terms of practically applicable parameters, commonly used grape parameters that are analysed with standard methods were used with consideration of all the ratios and grape parameters showing correlation and prediction value with the different wine sensorial quality parameters. These parameters, i.e. °B, titratable acidity, pH, pH:titratable acidity, and °B:titratable acidity, showed highly significant correlation with the parameters selected by stepwise regression. Their values are indicated along with the wine sensorial quality parameters in Fig. 12. Despite the different climatic conditions of the two years, values of the ratios were well repeatable. [The values of other more complicated ratios based on colour extraction and whole berry extraction (data not shown) would depend on the methods used during analyses]. The grouping of the ratios corresponded to the observed growth and physiological trends, indicating changes in source:sink relationships and interaction and readiness of the grapes for distinct wine styles.

Different terroirs may change the criteria for optimal ripeness *via* an advancement or retardation and even inhibition of specific processes and their products (Hunter & Bonnardot, 2002). This may lead to shorter harvesting periods (and thus a reduction in the options for different styles of wines) and an alteration in the ratios of the different berry components, particularly when excessive stress-inducing conditions are experienced by the vine. The growth conditions that the grapevine is subjected to should allow optimal metabolic activity in roots, permanent structure, canopy and grapes and the potential for these organs to develop and support each other until the desired grape quality and style is achieved. The better suited the terroir and the concomitant management, the higher the potential for obtaining higher grape and wine quality and different wine styles within a longer harvesting period. The pre-véraison period is equally important in creating improved metabolic functioning of the leaves and grapes; events during this period may be critical in the determination of eventual grape and wine quality (Carbonneau & Deloire, 2001; Hunter & Archer, 2001a, 2002; Ojeda *et al*., 2002; Hunter *et al*., 2004).

Conclusions

Ideally, the vineyard growth conditions should allow the prediction and distinction of different harvesting times, representing different styles of wine that can then either be made unilaterally or multilaterally by means of blending. Irrespective of the style of wine required, it is important that grapes are always harvested in a physicochemical state that would guarantee maximum (optimal) quality of the product for which they are intended. Cultivation practices should be applied in such a way that the full grape quality potential of the vine is expressed on the particular terroir. If the terroir and cultivation practices do not allow normal physiological performance and grape potential to be fully expressed, as is often the case in practice, wine quality and style options will be reduced. Judicious selection of terroir and long-term practices is therefore critical.

The study clearly showed that optimal ripeness can not simply be described by the maximum accumulation of grape components, but rather represents a complex, particular combination of physiological/biochemical changes (in leaves and grapes in particular growth phases), physical changes

(homogeneity of vine and canopy structure as well as bunch and berry size), and required grape/wine style and market preferences.

Optimal harvesting time for a particular style of wine could be illustrated by using classic parameters of which information can be easily obtained during the growth season in the vineyard and in the winery by producers and winemakers. The global applicability of the wine quality and style indicators found in this study (grape parameters and ratios) is currently further investigated. An extensive study on environmental impact (particularly soil water status) on grape optimal ripeness is also underway.

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Table 1. Correlations of Shiraz/R99 grape parameters/ratios with wine sensorial quality variables.

Grape Parameter/ratio	Total aroma intensity	Berry Aroma	Acceptability of acidity	Body	Colour	Total quality Impression
	BERRIES					
°B must	0.63	0.55	0.46	0.63	0.71	0.63
TA must	- 0.74	- 0.60	- 0.40	- 0.68	- 0.71	- 0.72
pH must	0.75	0.63	0.40	0.74	0.74	0.70
pH:TA	0.64	0.58	ns	0.64	0.69	0.63
°B:TA	0.61	0.56	ns	0.62	0.69	0.61
°B:pH	0.50	0.44	0.48	0.49	0.62	0.53
	SKIN					
Anth	0.76	0.59	0.66	0.67	0.57	0.64
Phenolics	0.73	0.59	0.56	0.64	0.57	0.63
Anth:Berry mass	ns	ns	ns	ns	0.48	ns
Anth:Berry vol.	0.39	ns	ns	ns	0.51	ns
TA:Anth	- 0.80	- 0.60	- 0.52	- 0.71	- 0.70	- 0.75
Malic:Sucrose	ns	ns	ns	ns	- 0.48	- 0.39
Tartaric:Glucose	- 0.55	- 0.57	- 0.40	- 0.67	- 0.54	- 0.57
Malic:Glucose	ns	- 0.45	ns	- 0.48	- 0.48	- 0.45
	WHOLE BERRY EXTRACTION					
Berry mass:Seed T	ns	0.62	0.52	0.54	0.63	0.50
Berry mass:Tannin	ns	ns	ns	ns	- 0.47	ns
Berry vol.:Seed T	- 0.56	- 0.63	ns	- 0.57	- 0.67	- 0.58
Berry vol.:Tannin	ns	ns	ns	ns	- 0.53	ns
TA:Phenolics	- 0.53	- 0.47	ns	- 0.53	- 0.59	- 0.56
TA:Seed T	- 0.82	- 0.73	- 0.61	- 0.77	- 0.79	- 0.83
TA:Tannin	- 0.67	- 0.54	- 0.46	- 0.61	- 0.70	- 0.67
pH:Seed T	- 0.50	- 0.62	ns	- 0.53	- 0.65	- 0.54
pH:Tannin	ns	- 0.38	ns	ns	- 0.55	- 0.42
°B:Tannin	ns	ns	ns	ns	- 0.42	ns
Berry mass:Anth	ns	ns	ns	ns	- 0.46	ns
Berry vol.:Anth	ns	ns	ns	ns	- 0.47	Ns
TA:Anth	- 0.69	- 0.50	- 0.49	- 0.61	- 0.66	- 0.68

°B = °Balling, TA = Titratable acid, Anth = Anthocyanin

All correlations are significant at 5 % or less; ns = non-significant

Table 2. Stepwise regression analysis of Shiraz/R99 grape parameters/ratios with wine sensorial quality variables.

Variable entered	Dependent variable/R^2
	TOTAL AROMA INTENSITY
TA:Anth (skin)	0.65
Berry mass:Anth (whole berry extract)	0.72
Berry volume:Anth (whole berry extract)	0.78
Anth (skin)	0.81
	BERRY AROMA
pH must	0.39
Berry mass	0.47
	ACCEPTABILITY OF ACIDITY
Anth (skin)	0.44
°B:pH	0.53
	BODY
pH must	0.55
Berry mass	0.63
Berry volume:Anth (whole berry extract)	0.70
	COLOUR
Berry pH	0.52
	TOTAL QUALITY IMPRESSION
TA:Anth (skin)	0.56
Anth (skin):Berry mass	0.62

°B = °Balling, TA = Titratable acid, Anth = Anthocyanin

All correlations are significant at 5 % or less

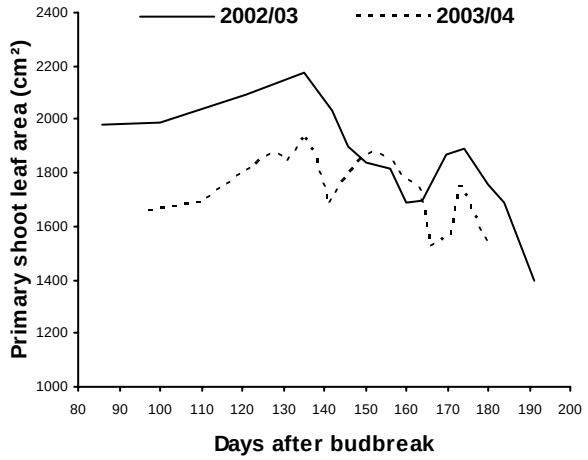

Fig 1a. Seasonal variation in primary shoot leaf area.

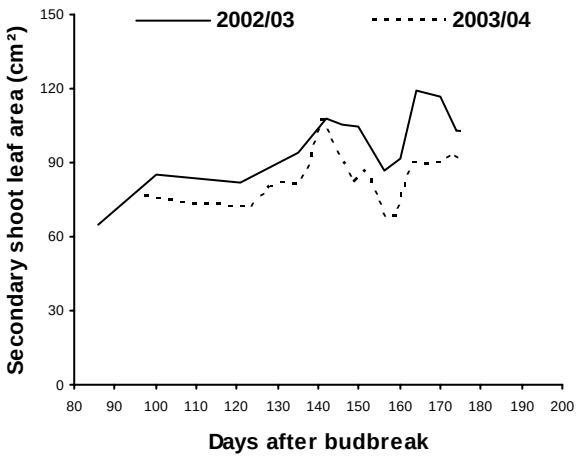

Fig 1b. Seasonal variation in secondary shoot leaf area.

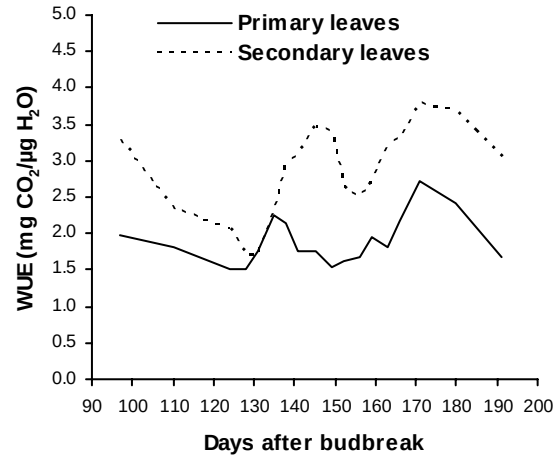

Fig 2. Seasonal variation in water use efficiency of primary and secondary leaves and the effect of berry ripeness level.

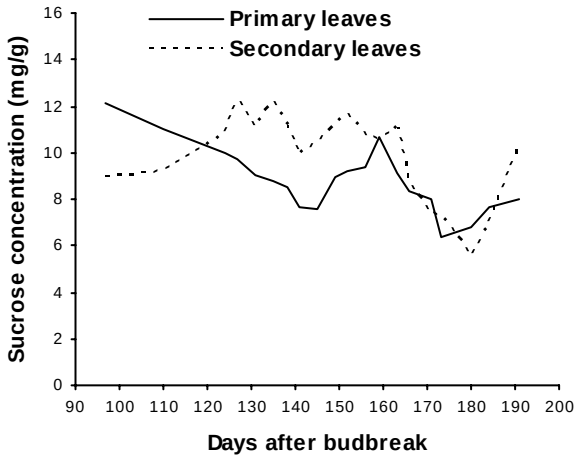

Fig 3. Seasonal variation in sucrose content of primary and secondary leaves and the effect of berry ripeness level.

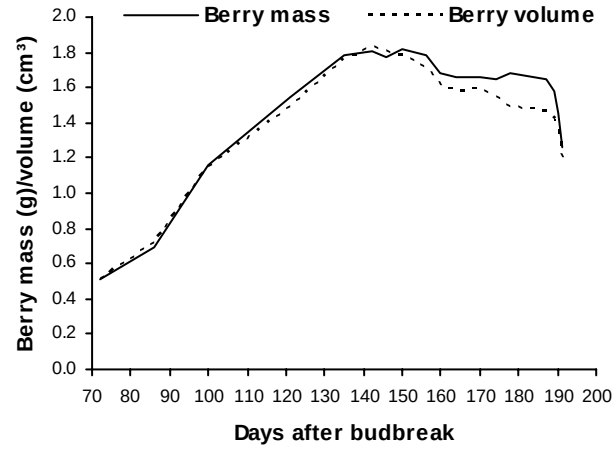

Fig 4. Seasonal variation in berry mass and volume and the effect of berry ripeness level.

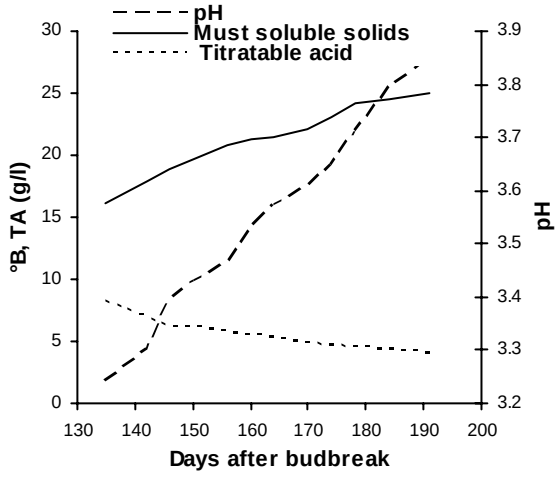

Fig 5. Must soluble solids, titratable acid, pH and the effect of berry ripeness level.

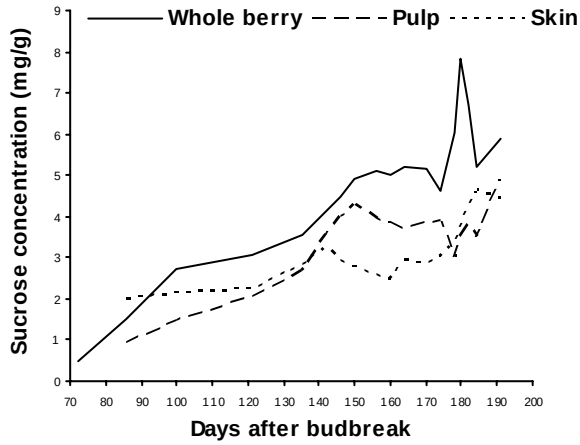

Fig 6a. Seasonal variation in whole berry, pulp and skin sucrose contents and the effect of berry ripeness level.

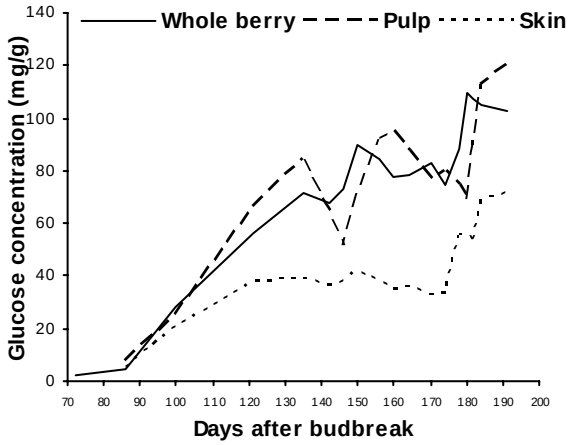

Fig 6b. Seasonal variation in whole berry, pulp and skin glucose contents and the effect of berry ripeness level.

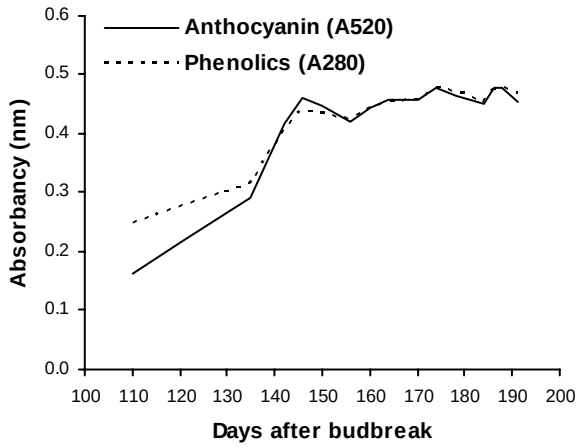

Fig 7. Skin anthocyanin and phenolic content and the effect of berry ripeness level.

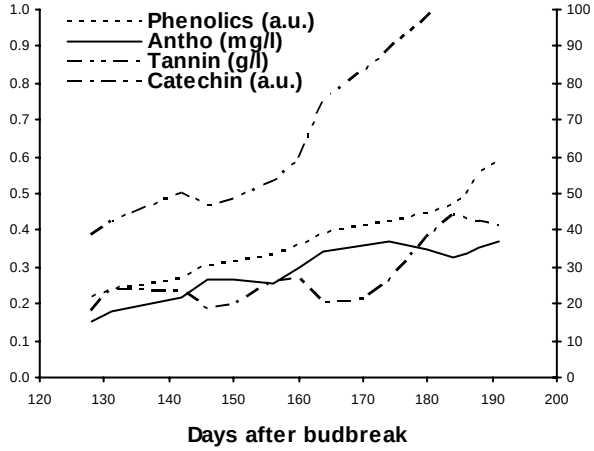

Fig 8. Whole berry phenolic content and the effect of berry ripeness level.

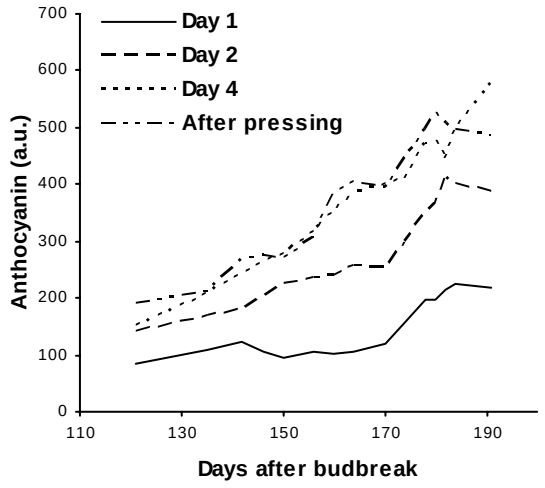

Fig 9a. Extraction of anthocyanin into wine during fermentation as affected by berry ripeness level and fermentation duration.

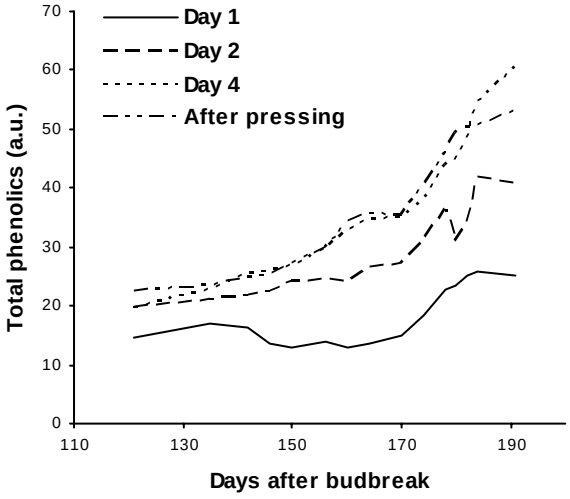

Fig 9b. Extraction of phenolics into wine during fermentation as affected by berry ripeness level and fermentation duration.

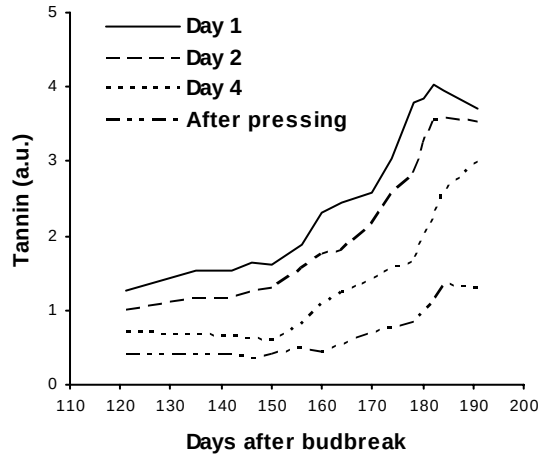

Fig 9c. Extraction of tannin into wine during fermentation as affected by berry ripeness level and fermentation duration.

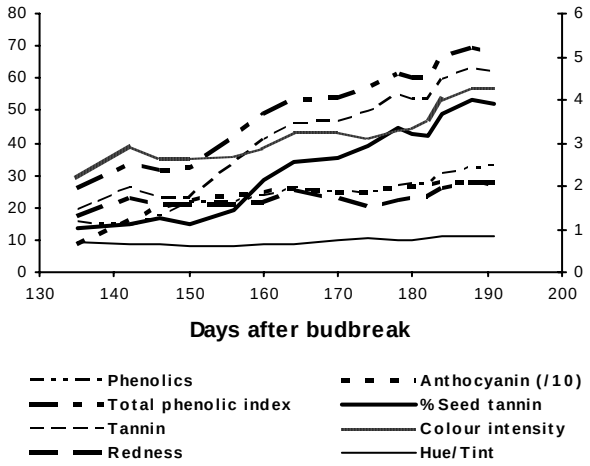

Fig 10. Wine phenolic content as affected by berry ripeness level.

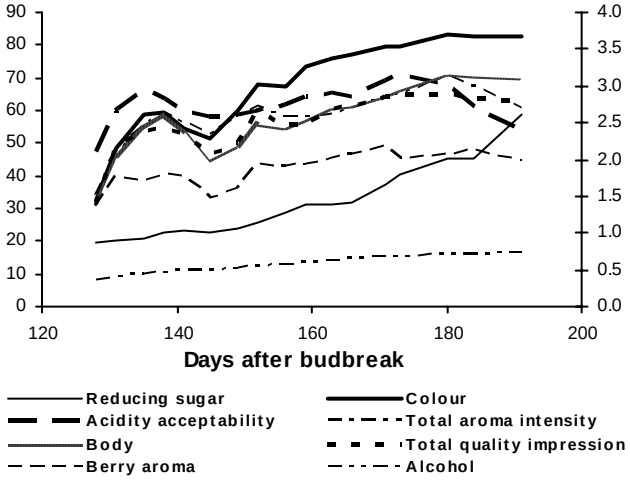

Fig 11. Wine sensorial quality, and alcohol and reducing sugar contents as affected by berry ripeness level.

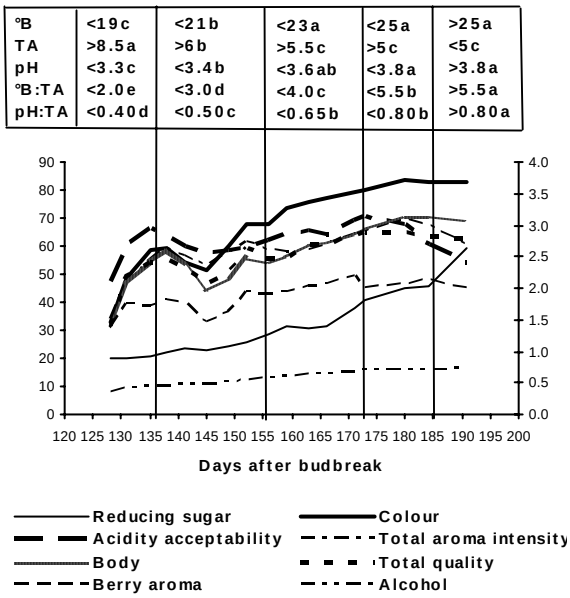

Fig 12. Grouping of different wine styles according to easily measurable grape parameters and ratios.